SURGERY
GYNECOLOGY AND OBSTETRICS
An International Magazine, Published Monthly

VOLUME 78 MAY, 1944 NUMBER 5

FECAL FISTULA

A. L. LICHTMAN, M.D., and JOHN R. McDONALD, M.D., Rochester, Minnesota

DESPITE progressive improvements in surgical technique, persistent fecal fistulas continue to be encountered at surgical clinics. Search of the literature failed to answer many of the questions that arose in observation of a group of cases encountered recently. In most studies, the fistulas were attributed to surgical faults, and there was little consideration of lesions in the intestinal wall. Because of this, one finds little discussion of the factors which tend to cause persistence of fecal fistulas despite repeated attempts at repair. It is only in the past 10 years that fecal fistulas related to granulomatous lesions of the intestinal wall have received adequate consideration.

This investigation was undertaken in an attempt to provide a sound basis for the study of the causes of persistence of fecal fistulas and the utilization of this knowledge in the application of the proper treatment for the cure of the fistula. We concerned ourselves with persistent fistulas originating in the small or large intestine (exclusive of the duodenum and upper part of the jejunum), which occurred as unforeseen complications of abdominal operations. From 1930 to 1941, inclusive, 590 cases of fecal fistula were encountered at the Mayo Clinic. In 58.2 per cent of these the external opening was in the right lower quadrant of the abdomen.

From the Section on Surgery, Mayo Foundation, and the Section on Surgical Pathology, Mayo Clinic.

Abridgment of thesis submitted by Dr. Lichtman to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirement for the degree of M. S. in surgery.

HISTORICAL

Before the work of Fitz, ulcerative disease of the terminal portion of the ileum was recognized as a common cause of fecal fistula. In the rush of enthusiasm involved in the recognition of the importance of appendicitis, the rôle played by other inflammatory lesions of the ileocecal region in formation of fistula was neglected for about 46 years. There was a tendency toward considering all granulomas of the ileocecal region to be of appendiceal or tuberculous origin.

Aretaeus of Cappadocia (circa 30–39 A.D.) incised an abscess of the right lower quadrant, producing a vesical and external fistula. Saracenus, in 1642, described a fecal fistula in a 50 year old woman who had an abscess of the right lower quadrant, which ruptured spontaneously, extruding 14 lumbricoid worms. The fistula closed spontaneously. Claudius Amyand, F. R. S., in 1735, described a fecal fistula developing in a hernia, in which the appendix and omentum had become incarcerated. At operation, he found that the appendix had been perforated by a pin, and ligation and excision of the appendix resulted in a cure of the fistula. In 1812, Copeland observed a fecal fistula resulting from an ileocecal abscess which healed after the removal of an oval calculus from the fistulous tract. With

TABLE I.—UNDERLYING PATHOLOGIC LESION IN CASES IN WHICH FECAL FISTULA DEVELOPED AFTER OPERATION

Basic underlying disease, process, condition or relationship for which operation was performed	Mayo and Schlicke* 1941	Rankin, Bargen, and Buie 1932		Ginzburg 1940
		Cases	Per cent	
Appendicitis	50	98	37	21
Pelvic inflammatory disease	25	44	17	10
Regional enteritis	11			14
Tuberculosis, intestinal or pelvic	24	35	13	7
Malignant tumors, intestinal or pelvic	16	16	6	2
Ulcerative colitis	4			1
Diverticulitis	9	22	8	2
Actinomycosis	1	4	2	4
Obstructive condition of intestine	6			
Intestinal perforation, traumatic	4	7	3	
Foreign body in abdomen		4	2	
Affection of spleen	2			
External hernia	2	4		1
Operations on the bile duct	1	4		
Operation for perforation of uterus		4		
Drainage of abscess due to Meckel's diverticulum		2		
Drainage of retroperitoneal abscess		2		
After resection of bowel (cause not stated)		5		
Indeterminate		13		
Total	155	264		62

*The series presented by Mayo and Schlicke included the cases observed at the Clinic from January, 1930, to December 31, 1934, inclusive. This paper includes cases observed up to December 31, 1941, inclusive.

their characteristic brilliance, Bright and Addison, in 1839, described the development of fecal fistulas following acute appendicitis and inflammatory lesions of the ileocecal region in those more fortunate cases in which an abscess pointed externally and ruptured spontaneously or was incised. Ginzburg, in 1940, reported 14 cases of persistent fecal fistula following laparotomy in cases of regional enteritis.

CLASSIFICATION

1. *Cause. Congenital.* Most fistulas of congenital origin terminate at the umbilicus and represent a patent omphalomesenteric duct. They are rare. None was found in this series.

Acquired. Pathologic or spontaneous fistulas, follow spontaneous rupture of a section of the intestinal wall due to infection, malignant lesion or impeded circulation, for example, perforated appendiceal abscess, diverticular abscess or strangulated hernia, or, in former days, typhoid fever. Internal or enteroenteric fistulas are formed in this manner. It is by this method that the body may care for obstructions in the gastrointestinal tract, spontaneously decompressing the bowel. Gastrojejunocolic, cholecystoduodenal, and vesicosigmoid fistulas are examples of this type.

Traumatic fistulas include those following gunshot wounds, perforating wounds and fecal fistulas associated with compound fractures and hemorrhages (Lockhart-Mummery).

Postoperative fistulas include: (1) *intentional,* those operatively created for decompression in obstruction, to rest a diseased section of bowel, or prophylactically to protect a freshly sutured bowel (colostomy, enterostomy); (2) *accidental* (Table I), those following operations involving malignant lesions, and those following inflammatory lesions of the intestines. (This is the group with which this study is primarily concerned.) The fecal fistula usually appears in the immediate postoperative period. Occasionally, however, there is an interval of as much as 6 to 12 months between the operation and the development of the fistula.

2. *Description of the fistulous tract* (17, 31, 13, 7, 32). *Artificial anus or lip fistula.* Intentional colostomy is of this type (Fig. 1a). There is continuity between the mucous membrane and the skin in many cases, and when a tract exists it is short. The defect in the intestinal wall is large. When the term "artificial anus" is used, it implies that the entire fecal stream passes through the fistula. Many fistulas of this type have a spur or promontory (Fig. 1a′) which separates the proximal from the distal loop of intestine.

Suppurative saccular fecal fistula (pyogenic fecal fistula) (Fig. 1b). Fecal or purulent material is discharged intermittently because of the interposition of an abscess cavity between the internal and the external opening. This type frequently is difficult to distinguish from

a sinus tract infected with Escherichia coli. Periodically, the rather small openings in the bowel will close and neither gas nor feces will pass. Recognition of this type is important because of the greater operative difficulty and poorer prognosis than in the other types. Fistulas maintained by a foreign body in the abdominal cavity are frequently of this type.

Tubular fecal fistula. A smaller portion of the feces passes through the tract than in cases of lip fistula. Tubular fistulas are single (Fig. 1c) or multiple (Fig. 1d) with reference to the internal or external openings.

3. *The site of termination of the fistula. Internal fistulas* (bimucous) originate in the intestine and empty into a more distal loop of intestine, the bladder, or the genital system. *External fistulas* empty by way of the anterior, posterior, or lateral abdominal wall. The vagina or the perineum is an occasional site of exit. In the case of the *combined fistula* (Fig. 1e) the tract is complex and tortuous, communicating internally with another segment of bowel or other structure and empties externally via the abdominal wall.

Some of the statistics from the literature on fecal fistula are given in Table II. Kelly and Hurdon quoted and added to Soennenberg's figures on the direction of rupture of appendiceal abscesses (Table III). Muehsam (38, 39) placed rupture into the vagina as the third most common variety. Drainage via the right fallopian tube is occasionally observed (2 cases in this series). Murphy in his clinics on fecal fistula presented a detailed description and classification of fecal fistulas. He included many unusual types of fistula.

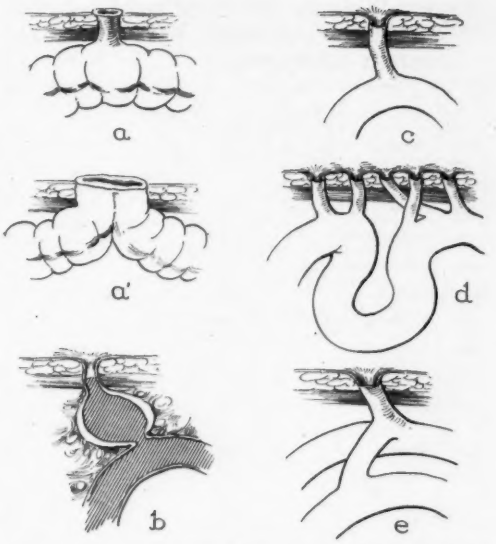


Fig. 1. Types of fecal fistula. a, Lip fistula (artificial anus); a', same with spur; b, suppurative saccular (pyogenic) fecal fistula; c, single tubular fecal fistula; d, multiple tubular fecal fistulas; e, combined internal and external fistula.

THE INCIDENCE OF FECAL FISTULAS

Table IV gives some of the reports of the incidence of fecal fistula after operations for acute appendicitis or other abdominal conditions. The series reported by MacLaren gives the incidence in 5,000 consecutive abdominal operations of all types as 1.5 per cent. When available, the percentage that healed by nonoperative means is included. The figures in our series are not available, because, in the majority (93.2 per cent) of the cases, the initial operation was performed elsewhere. In Eliot's experience, all fecal fistulas occurring after appendectomy healed spontaneously. The occurrence of fecal fistulas was attributed in most cases to faulty handling of the appendiceal stump or the cecal wall. Those interested in one method of appendectomy described an added incidence with the use of other methods. Muehsam (38, 39) attributed

TABLE II.—PERCENTAGES OF TYPES OF FECAL FISTULA REPORTED

	Rankin and Gorder	Mayo and Schlicke
Cases	264	155
Internal	10.6	....
External	82.9	....
Combined	7.19	....
Single	60.9	52.3
Multiple	30.68	28.1

TABLE III.—DIRECTION OF RUPTURE OF APPENDICEAL ABSCESSES (KELLY AND HURDON)

	Cases
Rupture through the abdominal wall	46
Rupture into the cecum (internal)	40
Rupture into other portions of intestinal cavity	11
Rupture into the peritoneal cavity	8
Rupture into the pleural cavity	6
Rupture into the urinary bladder	3
Rupture into the uterus	1

TABLE IV.—THE INCIDENCE OF FECAL FISTULAS AFTER APPENDECTOMY AND OTHER ABDOMINAL OPERATIONS

Date	Authors	Postoperative percentage incidence of fecal fistula	Cases in series	Percentage spontaneous closure	Remarks
1893	Porter	4.1	187		Figures quoted are all persistent fistulas
1894	Fowler [18, 19]	3.5	169		
1895	Van Lennep	5.5	118		
1900	Muehsam	16.3	441	63	First series
1903	Muehsam	6.6	815	62	Second series
1905	Kelly and Hurdon	3.5			
1918	MacLaren	1.5	5,000	80	Includes all abdominal operations
1926	Deaver	5.0	4,655	39	
1926	Gibson and Sherrill	1.2	1,583	88	
1926	Colp	1.1	2,841		
1931	Pfeifer and O'Connell	1.4	3,098		
1933	Lewis and Penick	(109 cases)		9	
1938	Ray	1.2	886	91	
1942	Ransom	0.8	1,067		
1942	Warren and Miller	13.9	43		Cases of regional enteritis
1942	Duley	2.7	417	82	

the reduced incidence in his second series to improvement in technique. While figures in appreciable numbers are not available, it would seem that the widespread use of sulfonamide drugs intraperitoneally will reduce the incidence of fecal fistulas appreciably. Little attention was paid by these authors to lesions inherent in the wall of the ileum and cecum which predispose to ulceration and formation of fistula. Postoperative fistulas which develop after intervals of as much as 6 to 12 months of apparent healing were not discussed. Factors involved in formation of fistula will be discussed later in this paper.

The improved understanding of granulomatous lesions of the ileocecal region has affected the operative treatment. On finding an inflammatory adherent mass involving the terminal portion of the ileum, the cecum and the appendix, one no longer automatically assumes that the lesion originated in the appendix. It is recognized that in regional enteritis, the external coats of the appendix may be infected secondarily. The overwhelming incidence of appendicitis has caused surgeons to overlook regional enteritis, tuberculosis, and malignant lesions of the cecum. Deaver stated that in the majority of the cases in which fecal fistulas later developed, he noticed ulcerations in the terminal portion of the ileum and in the cecum at primary operation. It is probable that in many of these cases the lesions were in reality those of regional enteritis. The more general use of conservative therapy and chemotherapy in pelvic inflammatory disease will probably reduce the incidence of fecal fistula from this cause.

TABLE V.—CAUSATION IN SPONTANEOUSLY DEVELOPED FECAL FISTULA (3 CASES)

	Cases
Spontaneous perforation around carcinoma of sigmoid.	1
Spontaneous perforation of multiple abscesses of abdominal cavity of unknown cause	1
Spontaneous perforation abscess diverticulitis	1
	3

Spontaneous establishment of an external fecal fistula is not common. Three such cases were encountered in this series (Table V). Haggard, in 1918, reported 2 cases in which fecal fistula followed spontaneous rupture of an incarcerated hernia containing gangrenous bowel. In his 3 other cases the fistula occurred after herniorrhaphy. Muehsam (38, 39) reported 3 cases in which the fecal fistulas were created by spontaneous rupture of an abscess in the right lower quadrant.

ETIOLOGIC FACTORS IN FORMATION OF FECAL FISTULA

In Table I are given some of the larger series of cases reported which present the pathologic lesion underlying the development of fecal fistulas. Those series published previous to 1932 do not include regional enteritis as a causative factor. No doubt, cases of regional enteritis were reported as appendicitis or, if the lesion showed a tubercle-like formation, as hyperplastic noncaseous tuberculosis. It is our purpose to study the proper relation of the latter granuloma to tuberculosis and regional enteritis. This will be reported at a later date. Because, during the early years following the

TABLE VI.—ORIGINAL LESION IN 408 CASES OF FECAL FISTULA OPERATED UPON AT THE MAYO CLINIC*

Basic lesion or operation from which fecal fistula resulted		Cases
Appendicitis		99
Fecal fistula after initial operation	65	
Amebic appendicitis	1	
Mucocele of the appendix	1	
After secondary operation for obstruction	34	
Regional enteritis		62†
Regional ileocolitis		9
Tubo-ovarian inflammatory disease (not tuberculosis)		49
Operations after septic abortions		3
Malignant lesions		35
Diverticulitis		28
Tuberculosis, tubo-ovarian		17
Tuberculosis, intestinal‡		17
Operations on benign lesions of uterus, tubes, or ovaries		14
Chronic ulcerative colitis		10
Operations about the gall bladder		10
Traumatic intestinal perforation, gunshot wounds, and so forth		8
In performance of herniorrhaphy		8
After multiple operations for adhesions		8
Actinomycosis		5
Miscellaneous		
Operations on volvulus, intussusception, and mesenteric thrombosis		5
Operations on benign tumors of bowel		5
Operations for repair of perforated duodenal ulcer		2
Operations on pseudomucinous cysts of ovary		2
Operations for impaction of gall stones		2
Operations for drainage of perinephritic abscess		2
Operations for resection of injured spleen		2
Operations for repair of diaphragmatic hernia		1
Drainage of subdiaphragmatic abscess		1
Drainage of prostatic abscess		1
Multiple intra-abdominal abscesses of unknown cause		1
Multiple intra-abdominal granulomas of unknown type		1

*Seventeen of the 408 patients operated upon had latent syphilis.
†In 42 of the cases of regional enteritis the initial operation was appendectomy or drainage of an abscess of the right lower quadrant supposed to be of appendiceal origin.
‡The term intestinal tuberculosis refers to so-called hyperplastic nonconseous tuberculosis, which contains atypical tubercles but in which tubercle bacilli cannot be demonstrated or cultured.

TABLE VII.—DISTRIBUTION BY AGE OF PATIENTS WITH SURGICALLY TREATED FISTULAS

Age, years	Patients
1–10	8*
10–20	35
20–30	107
30–40	90
40–50	86
50–60	55
60–70	27

*2 at age 3 years

TABLE VIII.—DURATION OF FISTULAS BEFORE PATIENT CAME TO CLINIC

Time interval	Cases
0–6 months	68
6–12 months	65
12–18 months	56
18–24 months	69
2– 5 years	64
5–10 years	66
10–15 years	14
15–25 years	5
45 years	1

general acceptance of acute appendicitis as an entity, the technique of the operation, the surgical security and the rapidity of the decision to operate were less favorable than they are today, the incidence of fecal fistula was undoubtedly greater. Most of the attention and discussion were devoted to acts of commission or omission by the surgeon, rather than to any intrinsic lesions in the intestinal wall.

The literature is replete with papers attributing fecal fistulas to unintentional injuries of the intestine during operations, necrosis by ligatures and misplaced sutures, improper ligation of the appendiceal stump, the use of rigid drains and blind energetic clamping.

In cases in which fecal fistulas develop some time after operation, we believe that the initial step is the formation of adhesions to the abdominal wall at the site of the incision. When there is active progression of the lesion in the intestinal wall, inflammation extends along the adhesions and sets a pathway for the fistula. When there is distal mechanical or physiologic obstruction, the formation of a fecal fistula is often a saving grace. Coffey stressed the rôles played in the development of fecal fistulas by postoperative incisional hernias with adhesions to the bowel, mesenteric traction, and the resulting disorganization of peristalsis.

Heineck (25, 26) reported 3 cases in which tapeworms were believed to play a part in formation of fistula. In this series, there was 1 case in which the ova of Taenia saginata were observed in the wall of the fistula. Gibney described the passage of Ascaris lumbricoides via fistulas. In 6 of our cases, these worms were passed via the fistula, but we believe that these intestinal parasites are purely incidental. Bannick described an internal fistula following appendectomy in a case of amebic appendicitis, with a stormy postoperative course.

TABLE IX.—TYPE OF FISTULA

Type of fistula		Cases
Multiple fecal		162
Single tubular		117
Suppurative saccular (pyogenic)		38
Combined fecal		37
Internal fistula plus multiple external	24	
Internal fistula plus suppurative saccular	10	
Internal fistula plus single tubular	3	
Lip fistula		30
Internal fistula		24

Barth, in 1890, reported 4 cases of fatal abdominal actinomycosis, 2 of which were appendiceal with persistent fecal fistulas. Short estimated that 1 to 2 per cent of appendiceal abscesses are actinomycotic and reported 5 cases of fatal actinomycotic appendiceal abscess with persistent fecal fistulas. Rowntree, Hinglais, and Brown also described fecal fistulas developing in cases of actinomycosis after operation. Five cases of actinomycotic fecal fistula were encountered at the Mayo Clinic in 12 years. In these cases repeated operations had been performed, and one may conclude that ordinarily actinomycotic sinus tracts do not communicate with the intestine. The fecal fistula is probably a result of operative manipulation. In 21 cases of actinomycotic sinus tract of the abdominal wall in which a fistula was suspected, no communication with the intestine was demonstrated.

Mucocele of the appendix is occasionally a cause of formation of fistula (Grodinsky and Rubnitz). One such case was encountered in this series. The prevention, cause, and treatment of fecal fistulas resulting from foreign bodies are self-evident and will not be discussed further.

STATISTICAL ANALYSIS

Five hundred and ninety patients who had fecal fistulas registered at the Mayo Clinic from January 1, 1930, to December 31, 1941, inclusive. Of these, 408 were treated[1] by some surgical procedure. The remaining patients did not undergo operative procedure because of medical contraindication, inadequate trial at spontaneous healing, or the decision of the patient. The nonsurgical cases were omitted from the discussion because the diagnostic data were not verified by laparotomy. Thus, many of the fistulas which were believed to be single preoperatively were found at operation to be multiple and complex. There had been previous attempts at repair of the fistula in 42.1 per cent of the cases. One patient had had 8 previous attempts at closure of the fistula.

Table VI presents the 408 surgically treated fistulas, listing as far as possible the basic lesion in the intestinal wall. When such a lesion could not be determined, it was assumed that the fistula developed because of inflammation, the separation of adhesions or injury to the bowel, and the case was listed under the

TABLE X.—SITE OF EXTERNAL OPENING

Site	Per cent
Right lower quadrant	58.2
Lower midline incision	22.0
Left lower quadrant	11.1
Other sites	8.7

[1]The surgical treatment in 128 of these cases was reported by Mayo and Schlicke. This included the cases from January 1, 1930, to December 31, 1934, inclusive.

TABLE XI.—SITE OF INTERNAL OPENINGS

Site	Cases	Per cent
Jejunum	14	3.4
Ileum	141	34.6
Terminal ileum and cecum	38	9.3
Cecum	59	14.4
Appendix	11	2.7
Colon (exclusive of sigmoid)	33	8.1
Sigmoid	55	13.5
Ileum and sigmoid	8	2.0
Cecum and sigmoid	12	2.9
Too complex to determine	37	9.1
Total	408	100.0

TABLE XII.—SUMMARY OF CASES IN WHICH FECAL FISTULAS DEVELOPED AFTER INITIAL OPERATION AT CLINIC

Cause or preceding operation	Cases
Resection of intestine for carcinoma	8
Perforation due to diverticulitis	3
Chronic ulcerative colitis, resection of colon	3
Regional ileocolitis, ileocolostomy for	2
Regional enteritis	2
Regional enteritis, drainage of abscess of right lower quadrant	1
After cholecystectomy	1
Drainage of pelvic abscess	1
After herniorrhaphy	1
After resection of intestine for benign tumor	1
After operation for volvulus	1
After resection for tuberculous ileitis	1
Drainage of actinomycotic abscess	1
Drainage of appendiceal abscess	2
Total	28

TABLE XIII.—POSTOPERATIVE RESULTS OF PROCEDURES FOR THE CURE OF FECAL FISTULA ACCORDING TO TYPES OF FECAL FISTULA.[1]

Result	Multiple fecal		Single tubular		Saccular suppurative		Combined fistula		Lip fistula		Internal fistula		Total
	1930–1935	1936–1941	1930–1935	1936–1941	1930–1935	1936–1941	1930–1935	1936–1941	1930–1935	1936–1941	1930–1935	1936–1941	
Cured	38	47	47	39	9	10	10	13	11	5	5	10	244
Persistent	22	14	8	3	3	4	3	2	2	2	1	0	64
Died in hospital	11	4	4	2	2	1	2	0	5	0	1	1	33
Dead 1 yr.	11	3	5	1	2	2	3	1	2	0	1	1	32
Inadequate follow-up	6	6	5	3	3	2	1	2	2	1	2	2	35
Total													408

[1]Each type is furthur subdivided into the cases occurring in 1930-35 and 1936-41 (6 year intervals).
Note:—Cures in cases of internal fistula and to some extent in cases of combined fistula are difficult to determine. One must depend on symptomatic recovery or roentgenologic evidence. When the operation was performed in one or more stages, the result of all stages as a unit is taken.

type of operation originally performed. Thus, while the appendix or a supposed appendiceal abscess was the site of the initial operation resulting in 169 of the fecal fistulas, in 70 of the cases there was found to be some other basic cause at the time of operation for the repair of the fistula. The list mentions 35 cases in which a malignant lesion was found to be the cause of the fistula. This is exclusive of intentionally created enteric or colonic stomas. Most of the cases represent operations upon the appendix or some abscess in the lower part of the abdomen in which the underlying malignant lesion was not suspected at initial operation. Internal fistula established spontaneously by malignant lesions was not included. Table VII presents the age of the patients who had fecal fistulas. The maximal incidence occurs in the third decade. Two cases occurred at the age of 3 years, both following operations for appendicitis with rupture.

The duration of the fistulas before the patients registered at the clinic is given in Table VIII. In some cases, the fistula was permitted to drain for a remarkably long period, in 1 case for 45 years. In some, the drainage was intermittent over a period of years.

The types of fistulas encountered are listed in Table IX, with their relative incidence. Multiple fecal fistulas are the most common type. This is contrasted with the earlier group presented by Mayo and Schlicke, in which the single tubular variety was more common. It is suggested that fewer fistulas are occurring as a result of operations on acute appendicitis, and a larger percentage now occur after operations on granulomatous lesions of the intestine.

Table X presents the sites of external openings. The majority of tracts open on the right lower quadrant of the abdomen (58.2 per cent). Miscellaneous sites, such as upper part of the abdomen, posterior lumbar region, vagina, bladder, perineum, and other less common sites, occurred in 8.7 per cent of the cases.

The internal openings are listed in Table XI. The ileum is the most common site of

TABLE XIV.—POSTOPERATIVE RESULTS FROM SURGICAL TREATMENT OF FECAL FISTULA FOLLOWING SOME OF THE MORE COMMON LESIONS

Result	Appendicitis	Regional enteritis	Regional ileocolitis	Pelvic inflammatory disease	Diverticulitis	Intestinal tuberculosis	Tubo-ovarian tuberculosis
Cured	78	44	4	28	14	9	7
Persistent	4	11	3	8	9	2	7
Dead postoperatively	7	3	1	2	2	1	—
Dead 1 yr.	7	2	1	7	3	3	—
Inadequate follow-up	3	2	—	4	—	3	3

TABLE XV.—OPERATIVE PROCEDURE FOR THE REPAIR OF FECAL FISTULA AND THE OPERATIVE RESULTS

Procedure	Cases	Cured		Persistent		Dead postoperatively		Dead 1 year		Inadequate follow-up	
		Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent	Cases	Per cent
I. Extraperitoneal procedures											
1. Curettage and packing*	21	6	28.6	10	47.6	0	0	2	9.5	3	14.3
2. Simple closure	16	10	62.5	2	12.5	2	12.5	1	6.3	1	6.3
II. Intraperitoneal procedures†											
1. a. Simple repair with excision of tract	108	75	69.4	9	8.3	7	6.5	7	6.5	10	9.3
b. Simple repair with Witzel enterostomy	9	5	55.6	0	0	1	11.1	2	22.2	1	11.1
2. Simple repair with plastic operation on intestine	16	12	75.0	1	6.3	0	0	2	12.5	1	6.3
3. Simple repair with removal of pelvic viscera	32	17	53.2	8	25.0	2	6.2	3	9.4	2	6.2
4. a. Side-to-side anastomosis without excision of fistula	38	22	57.9	8	21.1	3	7.9	3	7.9	2	5.2
b. Side-to-side anastomosis with excision of fistula	19	10	52.7	2	10.5	3	15.8	2	10.5	2	10.5
5. a. Resection of intestine and fistula with anastomosis	97	58	59.8	21	21.7	8	8.2	4	4.1	6	6.2
b. Resection of intestine and fistula with proximal enterostomy or colostomy	26	14	53.9	5	19.2	3	11.5	2	7.7	2	7.7
6. Obstructive resection (Mikulicz)	24	10	41.7	8‡	33.3	2	8.3	3	12.5	1	4.2
7. Colostomy only	14	4	28.6	6	42.9	1	7.1	2	14.3	1	7.1
8. Ileostomy only	4										
9. Drainage of abscess only	7										
10. Exploration only	6										
11. Appendectomy only	5										
Total	442										

*Only 2 of these done after 1936.
†The appendix was removed in addition to other procedures for the repair of the fistula in 19 cases. This does not include those removed during resection of the cecum. Similarly, intra-abdominal abscesses were drained in 15 cases.
‡In 4 a fistula persisted and in the other 4 the colonic stoma was not closed.

origin. When the fistula is multiple and finds origin in two different segments, they are listed separately. In cases of internal fistulas, the more proximal segment is taken as the origin of the fistula and the more distal as its external opening. In 37 cases, the points of origin and exit were too complex to determine.

Table V gives the causes in the 3 cases of this series in which the fecal fistula developed by spontaneous rupture of an abscess. In 28 cases, the fecal fistula developed after operation at the clinic. These are summarized in Table XII, which gives the causes or the operations after which the fistulas developed. Because of the multiplicity of the operations, no attempt was made to determine the percentage incidence represented. The remaining fistulas developed after operation elsewhere.

Tables XIII, XIV, XV, and XVI summarize the postoperative results providing the basis for the discussion of treatment. The tables are complex. They represent an attempt to determine (1) the relative success of the operations on the various types of fistula divided into two 6-year periods (Table XIII); (2) the relative success of operative treatment of fistulas resulting from some of the more common causes (Table XIV); (3) the relative results of the various operative procedures (Table XV); and (4) the relative incidence and type of postoperative complication for each procedure (Table XVI). By this method it is hoped that rational statistical help can be obtained for the application of the proper procedure to each case. Conclusions in the section on treatment are drawn freely from these tables.

The term "cured," as employed here, represents closure of the fistula as far as is determinable at the present writing, with a minimum of 9 months acceptable. Otherwise, the case is placed in the inadequate follow-up col-

TABLE XVI.—COMPLICATION FOR EACH TYPE OF PROCEDURE

Complication	Extra-peritoneal simple	Intra-peritoneal simple	Plastic	Removal pelvic viscera	Side-to-side anastomosis	Resection	Resection with Witzel	Mikulicz	Drainage of abscess	Total
General peritonitis		5		2	3	6	4	3	1	24
Shock		2			4	2	1	1	2	12
Ileus	1	2	1	1	4	3	3			15
Obstruction (partial)				3	5	2				10
Major pulmonary		1	1	1	2	2	1	1		9
Minor pulmonary	1	1	1	3	3	4	4			17
Draining sinus	1	1	1	1	2	2				8
Wound infection		2	2	1	3	2	2			12
Abscess. Local peritonitis		1		1	2	2	1			7
Wound disruption		1			2	1				4
Hernia	1	4		1	1	1		1		9
Urinary fistula	1		1		1					3
External hemorrhage						1	1			2
Erysipelas					1					1
Phlebitis					1					1
Parotitis									1	1
Duodenal fistula					1					1
Otitis media				1						1
Psychosis		1		1					1	3
Measles	1									1
Total complications	6	21	7	16	35	28	17	6	5	141
Operations	16	117	16	32	57	97	26	24	7	

umn. No matter how long the period of lag, if a fistula reopened, it was considered as persistent. A lag of as much as 1½ years was encountered. Death of a patient within 1 year removed the case to that column, even if the fistula was healed at the time of death.

PATHOLOGIC ANATOMY

The gross pathology of fecal fistulas has been the subject of many studies which have provided a basis for the classification of fecal fistulas. The microscopic structure has received less attention, although much can be derived from the classic works on granulation tissue in general. Therefore, 50 cases were selected from the material available in a 12-year period for more intensive study, in order to see if any tracts showed characteristics which would account for their persistence. The 50 cases were selected, without reference to the histories, from those cases in which there was no indication in the routine pathologic diagnosis of any reason for the persistence of the fistula. The usual diagnosis was inflammatory or granulation tissue. Specimens in which the fistula and both its internal and external openings were easily identified were employed. In 5 of the cases before 1933 a diagnosis of regional enteritis explained the persistence of fistulas previously believed to have followed operations for appendicitis. The histories were subsequently examined and the diagnosis was verified. Characteristics were sought which would show why, without obstruction below, the usual contraction of fibrous tissue failed to close these fistulas spontaneously. Why do some of the fistulas resist repeated attempts at closure?

Repeated sections were taken at several levels of the fistula and at the opening in the bowel. The sections were stained by hematoxylin and eosin, a modified glycogen-staining carmine for amebic inclusion bodies (Meriwether), carbolfuchsin for tubercle bacilli, a

modified Gram stain and Galantha's silver stain for spirochetes. Fixed frozen sections were made to study the contents of vacuoles created by solution in the lipid solvents used in making paraffin sections. Sections were studied under the polarizing microscope with and without a selenite crystal to identify doubly refractile inclusions.

Microscopic anatomy. It soon became apparent that the anatomic structure of the fistula was not haphazard, but that it had a definite histologic pattern. This was established as soon as the fistula was a few months old and an organized tissue developed. While few tracts presented as clear-cut a pattern as will be described, the structure is representative of all of them. The pattern was most prominent in the fistulas that contained imbedded talc. It should be understood that the pattern is changed by frequent hemorrhage, ulceration, and overgrowth of granulation tissue in local regions.

A. The vascular pattern. This is best described by division into three concentric zones.

The external zone. The outer zone is occupied by longitudinal and circular bundles of vessels. The longitudinal vessels pass up and down the tract and are frequently limited to two regions at opposite sides of the circumference. The circular vessels branch off the longitudinal vessels and pass around the periphery of the tract. The thickness of the vessel walls is proportionate to their size.

The medial zone. The vessels in this zone run in a radial fashion. They are straight and give off relatively few branches in this zone. They run between the bundles of fibrous tissue. The branches that do exist show panarteritic changes (Fig. 2). All degrees of proliferative medial thickening and obliterative endarteritis are seen. Several vessels are completely obliterated and histiocytes invade their substance. These represent former capillary tufts which have lost their function because of the increase in amount of, and contraction of, the fibrous tissue, tending to obliterate the fistula. In persistent fistulas, elements are present which tend to slow or suppress this natural tendency. At intervals, the radial arterioles break up into sinusoid structures inside of nodular masses of inflammatory cells, again to form single vessels after traversing the nodule. Lymphatic vessels are also prominent, both as perivascular and as independent vessels. In some fistulas sinusoid lymphatic structures surrounded by lymphocytic nodules are seen.

The internal zone. Vascular granulation tufts make up the tissue surrounding the lumen of the fistula. Capillary loops join the radial vessels. Where the capillaries curve or branch, their diameter is markedly increased. At the border of the tract, 3 to 5 concentric loops lie in close proximity, separated from the fecal stream by a thin syncytium of histiocytic cells. Small hemorrhages are common here, and a mass of free erythrocytes and hemosiderin may be seen lying among ghosts of ruptured capillaries. Where squamous or intestinal columnar epithelium has covered the vascular tufts, they maintain their structure beneath it, creating papillae and pegs or resembling intestinal villi.

B. Fibrous tissue. At the inner portion of the medial zone, stellate fibroblasts can be seen replacing the granulation tissue with a more fibrillar material. As one examines the external zone, there is more collagenous material present than in the medial zone. The direction of the fibrils follows the long axis of the original early fibroblasts. In the main, the inner portion of the medial zone has circular bundles while external to this the bundles are longitudinal. The bundles in the external zone run longitudinally. Blood vessels have a fibrous sheath around them and in their early formation, early fibroblasts can be seen with their axes parallel to the vessels. The longitudinal sheaths surround the nerves and vessels outside the perineural or perivascular lymphatics.

In some cases, the collagenous tissue was doubly refractile under the polarizing microscope. This may be evidence of early degeneration of the collagen fibrils. These fibrils looked normal in sections stained with hematoxylin and eosin and examined under ordinary light.

C. The granulation tissue. The internal portion of a fecal fistula consists of well organized granulation tissue. The inflammatory cells assume a definite relationship to the vas-

cular structure. Although the type of cell that was predominant matched the type of cell most common in the lesion in the intestinal wall, no cell or arrangement was found to be characteristic of any of the etiologic agents observed. Thus, in some cases of regional enteritis the histiocytes were prominent, in others the plasma cells and in still others the lymphocytes. When more is known about the causes of these intestinal lesions, it is possible that each of these cells will represent a particular type of inflammatory response or stage in the development of the lesion.

Because of the complexity of the condition, a somewhat composite picture of fistulas studied will be presented. The reader should remember that in each tract one or two of the cell types and arrangements predominate. The histiocytes follow the vascular structure closely. Frequently they load the perivascular lymphatics, forming sheaths for the vessels. At intervals, the sheaths bulge out into nodular masses, and when the nodules are numerous, they become confluent, so that the perivascular distribution is not apparent. In the medial zone the vessels may form sinuses which provide the structural network of the larger histiocytic nodules. Plasma cells, multinuclear histiocytes, and foreign body giant cells are associated in varying numbers. In a few cases in which a large giant cell had completely surrounded a blood vessel, it was interesting to note that the vessel wall and endothelium were not visible in the portion cuffed by the giant cell. Lymphatic vessels also undergo formation of sinuses.

The conglomerations of histiocytes are more common at the branching of vessels and absent at the dilated curved portions. The histiocytic sheath becomes thicker as the vessels approach the internal zone. Where the massed capillaries form loops at the lumen of the tract, the histiocytic cells fuse and form a continuous endothelium-like layer separating the granulation tissue from the fecal stream. Where regions of hemorrhage are present, the phagocytes are loaded with hemosiderin. Ingested bacteria and bacteria clinging to the walls of the histiocytes are present in moderate numbers close to the lumen but are rare deeper in the tissue. In recently formed

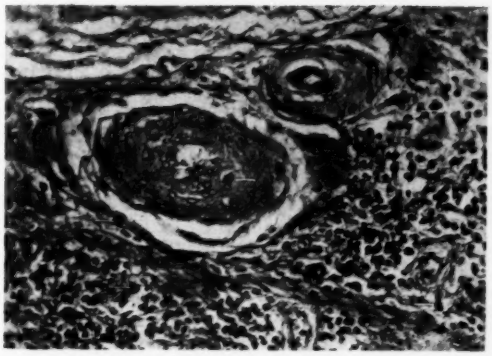


Fig. 2. The vessels of the medial zone that connect the radial branches show panarteritic changes. In the small vessel the lumen is almost obliterated. Medial thickening is an early change in the vessels (hematoxylin and eosin, ×175).

tracts or in ulcerated regions of old tracts, polymorphonuclear leucocytes with ingested bacteria can be seen for a short distance along the perivascular lymphatics.

In tracts in which lymphocytic infiltration predominates, the arrangement is less clear. Large regions of the internal and medial zone are occupied by masses of lymphocytes. In the medial zone, large endothelial cells with finely reticulated nuclei are intermingled. True lymphoid nodules with pale central cells and a blood vessel are present in small numbers. Occasionally, one sees a nodule whose center is occupied by larger cells which are endothelial in type. Their fibrillar processes form a fine network in the nodule. No vessel is present in these. In the external zone, there are irregular masses of very deeply stained lymphocytes with very little cytoplasm. Between the lymphocytes there are comma-shaped streaks of densely staining chromatin, probably representing pycnotic nuclear material.

Mast cells are frequent in the areolar connective tissue, closely intermingled with the stellate fibroblasts.

In the 50 tracts that were studied in detail, the predominant type of cell was tabulated. Histiocytes were most common in 19 (38 per cent), plasma cells in 10 (20 per cent), lymphocytes in 7 (14 per cent), polymorphonuclear leucocytes in 1 (2 per cent), and in 13 (26 per cent) no particular cell was predominant. In

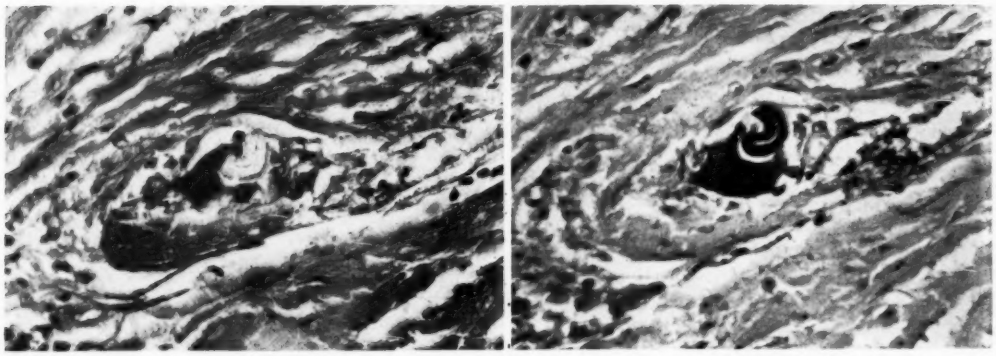


Fig. 3. A cotton fiber in a foreign body giant cell. The section at left is stained with hematoxylin and eosin; the section at right is stained with a modified Best's carmine and the fiber stains bright red (×317.8).

3 tracts eosinophils were abundant. There were tubercle-like structures in 5. As has been stated, no relation between the etiologic agent and the type of cell could be established, except that in 3 of the 4 cases of tuberculosis included in this group, the lymphocyte was the most prominent cell.

D. Contents of the foreign body giant cells. Twenty-seven (54 per cent) of the tracts contained foreign body giant cells in appreciable numbers. Study of their contents provided one of the most interesting and thought-provoking aspects of this work.

Small refractile insoluble fibers were found in 7 (14 per cent) of the tracts. In sections stained with hematoxylin and eosin, they appeared to be laminated. When they were stained with carmine or methylene blue, the outer portion stained, while the central portion or core remained colorless (Fig. 3). Under the polarizing microscope, they were compared with control fibers embedded in animals and definitely identified as cotton fibers. Since these were cases in which reoperation had been performed, it is likely that the fibers were initially introduced by the vigorous swabbing, grasping, and packing away of tissues with dry gauze sponges. The presence of these fibers and their possible significance in maintaining these fistulas should condemn the practice.

Furthermore, in 4 (8 per cent) of the tracts, crystals of magnesium silicate (the main component of talc) were identified by the polarizing microscope—with and without a selenite crystal (Fig. 4). Here, again, the foreign

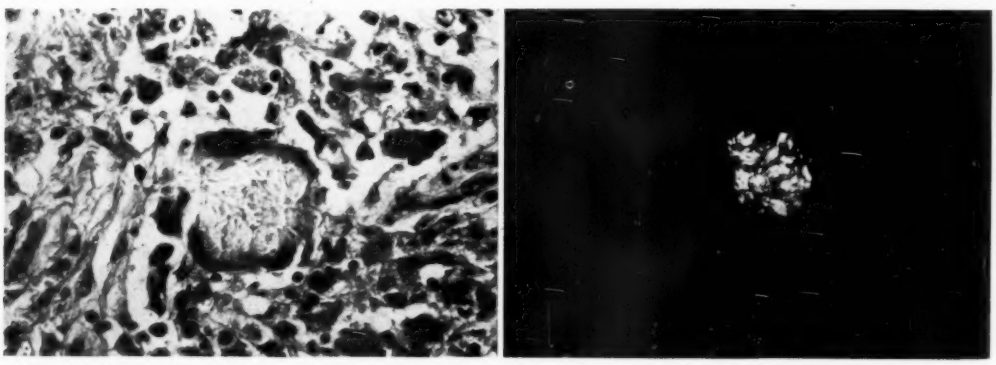
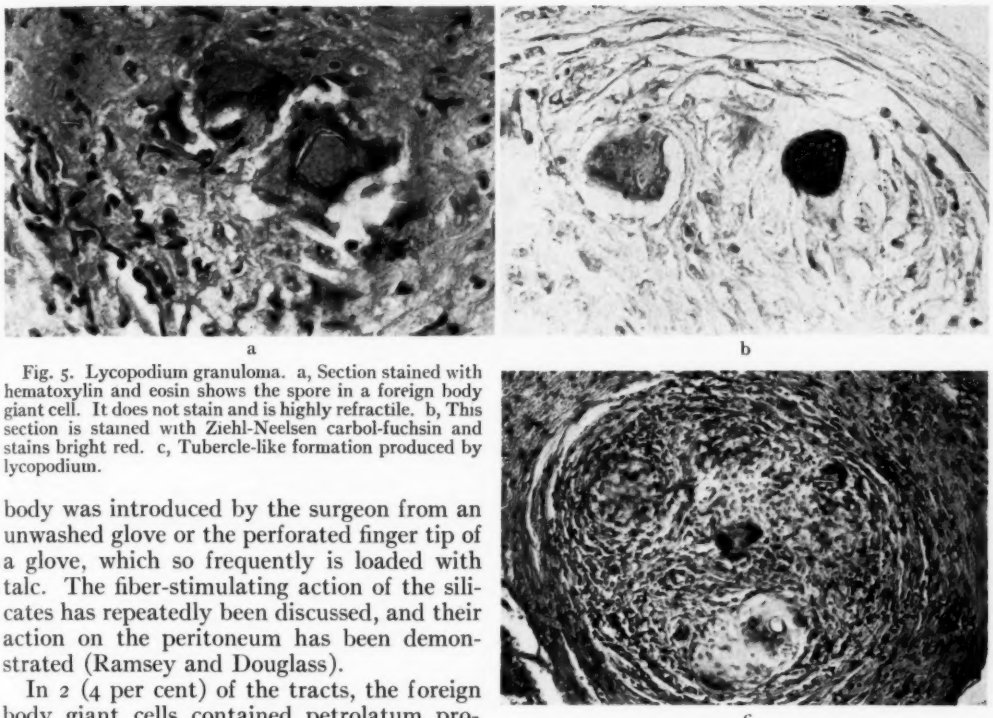


Fig. 4. Particle of talc (magnesium silicate) embedded in foreign body giant cell. The section at right shows the same field under the polarizing microscope (hematoxylin and eosin ×320).



a b c

Fig. 5. Lycopodium granuloma. a, Section stained with hematoxylin and eosin shows the spore in a foreign body giant cell. It does not stain and is highly refractile. b, This section is stained with Ziehl-Neelsen carbol-fuchsin and stains bright red. c, Tubercle-like formation produced by lycopodium.

body was introduced by the surgeon from an unwashed glove or the perforated finger tip of a glove, which so frequently is loaded with talc. The fiber-stimulating action of the silicates has repeatedly been discussed, and their action on the peritoneum has been demonstrated (Ramsey and Douglass).

In 2 (4 per cent) of the tracts, the foreign body giant cells contained petrolatum producing a paraffinoma-like reaction. Looking back again, one can assume that this originated from a petrolatum gauze drain. It brings to mind the oft repeated admonition against the use of petroleum derivatives as lubricants in any body cavity, because of the occasional disastrous result.

In 1 of the tracts there was a granuloma due to the spores of the moss Lycopodium (Fig. 5). A tubercle-like formation was noted in this case.

Four of the tracts showed ingested crystalline material which was soluble in the lipid solvents employed in embedding. In the fixed frozen section these empty spaces were identified as cholesterol esters. When the spicule was large, the foreign body giant cell was seen to engulf only a portion of the crystal bundle, usually the more ragged portion.

Five of the tracts showed large numbers of ingested cells in various degrees of degeneration. In 3 the foreign body giant cells contained vacuoles which occupied a major portion of the cells. The fluid contents were not identified. These foreign body giant cells were closely associated with blood vessels.

E. Miscellaneous and degenerative changes. A curious observation was made on 7 (14 per cent) of the tracts. On examination with polarized light at the point of extinction, multiple, minute, brilliantly refractile specks were seen. They were too small to identify and did not show any color. Some were in foreign body giant cells while others did not have any apparent reaction around them. This is mentioned because 6 of the 7 tracts showing this were among those on which operation had been performed most frequently or which had been most obstinately persistent without apparent cause. The significance of the refractile specks could not be determined.

Foam cells were present in 5 of the tracts and in 3 cases were so numerous as to create xanthomatous regions. Colloid degeneration was present in 2 tracts. In 2 cases the collagenous fibrils were doubly refractile and

showed clearly in polarized light. The significance of this phenomenon is not clear. It may represent early degeneration. Myxomatous degeneration was noticed in 3 tracts.

F. The lining of the tract. As has been mentioned, the granulation tissue bordering on the lumen is arranged as concentric tiers of capillary loops covered by a single layer of flattened histiocytic cells. Most of the tubular tracts maintain this arrangement in their midsections even after years of function. The outward funnel-like advance of the intestinal epithelium is more rapid than the progress of squamous epithelium inward. Microscopically, the intestinal epithelium advances in small outlying crypts in which the deeper parts are covered by young columnar cells, while the exposed portions still maintain their histiocytic covering. When completely covered, the granulation tufts show a superficial resemblance to intestinal villi. The squamous epithelial border, however, is sharper with a heaped-up margin and a short slope of advancing cells. When the granulation tufts are thus covered a resemblance to pegs and papillae is found. While contact is found in lip fistulas and intentional colonic stomas, no tubular tract of any length was encountered in which the squamous epithelium actually contacted the intestinal epithelium. In hemorrhagic and in suppurative regions no lining of the tract was seen. The tissue lining the tract in the 50 cases was as follows: histiocytic, 23; cecal, 8; squamous and cecal separated by histiocytic section, 6; squamous, 4; ileal, 2; squamous-cecal (lip), 2; histiocytic with section of suppurative membrane, 2; degenerating fibrous tissue, 2; and suppurative membrane, 1.

The external border of the tract which separates it from the peritoneal cavity is composed of a rather acellular compact layer of fibrils. Such cells as exist are poorly preserved, pycnotic and difficult to distinguish. It could not be clearly determined whether they were histiocytes, serosa cells, or fibroblasts.

G. Nervous tissue elements. In 10 (20 per cent) of the tracts nerve fibers and ganglion cells were found to have extended into the tract. This occurred only in those tracts in which the associated intestinal lesion showed marked hypertrophy of the nerve bundles and myenteric plexus. Although slightly more common in cases of regional enteritis, this hypertrophy seemed to represent another phase of the reaction of the intestine in chronic inflammation. The hypertrophy of nerve tissue seemed to be most marked in those cases in which there was an exceptionally excessive production of fibrous tissue. In these tracts nerve bundles and ganglionic cells were found for as much as 5 centimeters from the intestinal end of the fistula. In other cases large cells containing pale blue cytoplasm with immense reticulated nuclei and clear interreticular spaces were seen. It could not be determined whether these were of neurogenic or endothelial origin.

FACTORS WHICH MAINTAIN FISTULAS

Most fistulas in which there is not obstruction in the bowel below or specific infection or malignant lesions to maintain them close spontaneously. Some, however, are obstinately persistent and defy repeated attempts at closure. It is in this group that we are particularly interested.

Senn stated that the mucosal lining of fistulous tracts prevented their healing. Kelly and Hurdon attributed the failure of closure of the tracts to rigid fibrous walls, also claiming that fistulas from the ileum were rare. Coffey in an extensive study discussed the rôle of herniation in the abdominal wall in the maintenance of fecal fistulas. Von Mikulicz and Kausch and Forgue attributed great importance to the peristaltic traction on the afferent and efferent intestinal loops and traction of the mesentery against the adhesions to the abdominal wall. Agreeing with Coffey's views, Lewis and Penick added the factor of intra-abdominal pressure in the maintenance of fistulas and the production of spurs. They stated that long tortuous tracts tend to heal spontaneously. In Deaver's experience, however, such tracts usually required operative closure. Erdmann and Ransom stated that tracts originating in the ileum tended to persist.

In this series a hernia of the abdominal wall was noticed in 31.3 per cent of the cases. It must be remembered that these patients registered at the clinic after prolonged suppuration

and drainage from the original wound, after long persistence of the tract, and in 42.1 per cent of the cases after repeated attempts at closure elsewhere. In the material studied here the following reasons for persistence of the fistula were found:

1. There is a distinct, active lesion in the intestinal wall at the fistulous opening which prevents spontaneous closure. Operative closure can be successful only if this diseased segment is excised.

2. Foreign substances such as cotton fiber, talc, lycopodium, petrolatum, and products of degeneration embedded in the fistulous tract itself may alter the processes necessary for spontaneous closure of the fistula.

3. The defect or diseased portion in the intestinal wall may be too large for spontaneous closure, since contraction of scar tissue sufficient to close the fistula would produce constriction of the intestinal lumen. Here also resection of the diseased though quiescent segment of the intestine is essential for closure of the fistula.

THE DIAGNOSIS OF FECAL FISTULAS

The diagnosis of external fecal fistulas is made apparent by the nature of the discharge. In cases in which the external opening is small, sinus tracts infected with Escherichia coli can simulate the fecal discharge. In such cases feeding of insoluble or indigestible substances easily identified in the discharge establishes the connection with the bowel. In fistulas which discharge intermittently the passage of gas indicates a small opening in the bowel. A careful history is essential to the diagnosis. The presence of a foreign body must be ruled out.

When the diagnosis was in doubt, Judd suggested the injection of bismuth petrolatum paste into the tract. With repeated roentgenography one may determine the loss into the bowel. In present-day practice many radiopaque substances are available. To determine the site of origin of the fistula Senn advised injection of hydrogen gas with auscultation over the cecal region. If the gas escaped quickly without a gurgle, it indicated a fistula from the large intestine. If escape occurred after an interval with gurgling as the gas passed the ileocecal valve, the fistula originated in the small intestine.

The diagnosis of internal fistulas taxes the ingenuity of the physician. Careful roentgenoscopy with barium in the intestine will usually give suggestive evidence. The function of intentionally created anastomoses is commonly studied in this manner. With unusual fistulas special investigations are performed. Pool and Miller discussed the diagnosis of vesicoappendiceal fistulas. In their case catheterization of the tract by cystoscopy with the injection of an opaque medium demarcated the connections. In fistulas associated with the genital tract, the simultaneous use of barium in the intestine and injection of a radiopaque substance by catheterization of the external opening may be used for diagnosis. Thus by barium enema and hysterosalpingography one may outline an appendicosalpingeal fistula. Sigmoidoscopy is useful in diagnosis of fistulas originating in the sigmoid. By this method the internal opening was brought into view in 14 of the cases studied. While it may seem academic to subject the patient to such studies when the diagnosis is obvious, these methods give important preoperative information as to the condition of the intestine at the opening of the fistula, its function and, most important, the patency of the intestine distal to the fistula. In complex multiple and combined fistulas the diagnosis of connections is difficult even after direct observation at laparotomy.

Because of the poorer prognosis and more difficult operative treatment of suppurative saccular fecal fistulas it is wise to establish the diagnosis beforehand. These patients give a history of intermittent feculent and purulent discharge depending on the patency of the communication between the intestine and the abscess cavity. In this series it was noted that the only cases of fistula in which there was a history of hemorrhage from the tract were of this type. In 6 cases the amounts of blood were small, while in 3 cases the hemorrhages were severe.

Further, one must mention the lag that frequently occurs between operations and the development or recurrence of fecal fistulas in cases of regional enteritis. Periods of apparent

healing for as much as 6 to 12 months after appendectomy or repair of fistula performed in such cases were noted. Development of a fecal fistula after obvious healing of the incision following appendectomy should suggest the possibility of regional enteritis.

TREATMENT

Discussion of the treatment of any surgical complication properly begins with a plea for prevention. Reduction of the incidence of postoperative fecal fistulas should follow greater understanding and recognition of the lesion in the intestine, application of the proper procedure and surgical care, the intraperitoneal use of sulfonamide drugs in the presence of inflammation, and realization that finely divided substances like cotton fibers, talc, lycopodium, and petrolatum may produce granulomas in the peritoneal cavity.

The management of fecal fistulas at the Mayo Clinic has been described by Dixon and Deuterman, Schlicke and Dixon, and Mayo and Schlicke. Much that is written here is a recapitulation of these articles.

Spontaneous healing. Spontaneous healing of most postoperative fecal fistulas will occur. The larger series report spontaneous closure in from 39 per cent (Deaver) to 91 per cent (Ray) of the cases. Several smaller series report 100 per cent spontaneous closure after operations for acute appendicitis (Eliot). Experience has taught that a 6 to 12 month trial at spontaneous closure should be allowed before any operative treatment. Gage (quoted by Kelly and Hurdon) described a fistula which closed spontaneously after 7 years of drainage. The greater the length and the more tortuous a fistula, the greater is the tendency toward spontaneous healing. These same characteristics tend to make the operative dissection more difficult. Before one proceeds on a trial of conservative therapy, the presence of a foreign body in the tract should be ruled out, for in such cases operative removal is essential to a cure.

Nonoperative measures which promote healing. 1. For higher intestinal fistulas. The more fluid the drainage from the fistula, the greater is the debilitation of the patient, introducing many problems during the period of observation. The loss of electrolytes, enzymes, and nutritive material alters the normal economy of the body and necessitates replacement of essential substances by enterostomy or by intravenous and subcutaneous therapy. The closer the fistula is to the duodenum, the greater is the threat to life.

Continuous suction by any one of a number of ingenious methods is of threefold benefit. (1) It promotes healing by keeping the fistula empty and collapsed. By slight reduction of the intestinal pressure it promotes a more normal status and may tend to reduce the flow of intestinal juices and the accelerated emptying time of the stomach. (2) It prevents excoriation of the skin by the trypsin and other intestinal contents. (3) It provides a simple method of estimating the loss of fluid and electrolyte by measuring the fluid aspirated. In an occasional case the fluid can be returned to a distal loop of bowel. The suction devices described are numerous and often make use of common household items such as coat hangers and pouring caps from sugar dispensers. In any device a small opening in the fenestrated tube should be outside the stoma, preventing adhesion of the wall of the tract and the accumulation of excessive suction.

Dixon and Deuterman employ a well made of kaolin and adhesive plaster. Other authors advise the use of milk protein, olive oil, and egg white in the diet to provide a menstruum for enzymes and bile present. Surface excoriation is further prevented by the local application of beef broth and Witte's peptone, milk powder, aluminum powder or paste, spraying with 10 per cent tannic acid, or the application of tenth-normal hydrochloric acid. When infection is present, the use of 5 per cent sulfathiazole in a heavy petrolatum base is beneficial. Tub baths followed by exposure to air under a lighted hood improve the tone of the skin. After the exclusion of inflammation the fistula may be plugged with iodoform gauze saturated with 1 per cent camphorated oil, or chewing gum. Even if this is not instrumental in closing the fistula, it gives the patient and the skin a period of rest. A variety of specially cut T tubes have been employed.

2. For lower ileal and colonic fistulas. In this portion of the intestine much of the nu-

tritive value, fluid, electrolytes, and nonexpendable substances in the fecal stream have been absorbed, and the hazards are diminished during the trial at spontaneous closure. The incidence of spontaneous closure in this region is greater than in more proximal segments of the intestine. A high caloric, low residue diet is fed and the volume of fecal drainage is diminished. If the skin is indurated, 5 per cent sulfathiazole in a heavy petrolatum base or aluminum paste or powder may be employed. Many devices for plugging the fistula were employed formerly. Beck's bismuth paste was abandoned, because of the danger of bismuth poisoning. There are still occasions for the use of chewing gum, iodized oil, or iodoform gauze. Marshall and Lahey, in 1938, described a simple double button device. Before the employment of any of these, inflammation must be excluded; hence they should never be used in the treatment of suppurative saccular fistulas. They may be used when the patient is a poor surgical risk and is losing ground and are occasionally successful in healing a fistula in which the discharge is small and intermittent.

Preoperative care. Before operation the patient's protein, carbohydrate, electrolyte, fluid, blood, and vitamin reserves are evaluated and readjusted. A nonresidue diet is given. The patency of the bowel beyond the fistula is again established. In inflammatory lesions maximal subsidence of the inflammation is secured by rest in bed. Although sufficient experience is not yet available, it appears that preoperative oral administration of 2 to 4 grams of succinylsulfathiazole 6 times a day for 3 days is of distinct value in the more complex fistulas. Sodium phosphate catharsis for 2 days before operation is common. Colonic irrigations with saline solution in the knee chest position and irrigations via the fistula, if possible, are given for several days. The condition of the skin may be improved by 5 per cent sulfathiazole ointment. Maceration or induration of the abdominal skin should be cleared up before an operative incision is attempted. In high intestinal fistulas the prothrombin time should be determined and vitamin K administered, if indicated. The patient should be in as good condition as possible in preparation for a difficult operation with a high incidence of failure and a formidable mortality rate.

Surgical treatment. The presence of a fistula with an unknown course and having an indeterminate number of internal relations prevents any surgical approach with a preconceived idea. By the very nature of the development of the fistula, laparotomy is bound to present a field distorted by adhesions and the surgeon must possess a knowledge of facts concerning the chances of cure and respective mortality rate for each etiologic lesion causing fistulas. Thus in the cases presented here the rate of recurrence after attempt at repair in each category was as follows: postappendectomy, 4.0 per cent; regional enteritis, 17.8 per cent; diverticulitis, 31.0 per cent. A common cause for failure in these operations lies in the failure to close all the openings in the intestine. Even after extensive resections an obscure internal fistula resembling an adhesion will cause a persistence of the fistula.

A. Extraperitoneal procedures. 1. Curettage and packing. Indications for this procedure are as follows: (1) when biopsy is carried out; (2) when a foreign body is suspected; (3) when the patient is too debilitated for any more extensive procedure; or (4) when it is believed that a little freshening will promote granulations and contraction where the tract is well lined by epithelium. It is not very effective (28 per cent cures) and is usually successful only in hastening the course in a fistula that already shows signs of closing. It was the only procedure in 19 cases between 1930 and 1935, while between 1936 and 1941, although it was performed many times, it was the total procedure in only 2 cases.

2. Simple closure—extraperitoneal (Smith and Coffey). This is the simplest closure. Here the skin around the stoma is freed and the walls of the fistula are dissected away from the abdominal wall. A probe may be used to delineate it; otherwise it is plugged or closed to prevent contamination. The dissection is carried down to the peritoneum, which is pushed back so that the fistula can be clamped and excised with the knife or cautery. The fistula is excised with a longitudinal incision

in the intestinal wall. The mucosa is inverted with 2 or 3 rows of sutures in a transverse direction. Five grams of sulfathiazole are dusted in the area and the abdominal wall is closed in layers. A drain may be inserted down to the fascia. This method is in wide use in the closure of intentional colonic stomas after the spur has been crushed. It is the procedure of choice in some cases of fistula. Marshall and Lahey advised its use when the fistula is thin and small and the internal opening is small. When the skin is in poor condition, the closure of the skin can be postponed. The method possesses certain inherent disadvantages. It is difficult to judge the extent of the lesion in the intestinal wall, the presence of adhesions or small internal fistulas or encroachment on the lumen by narrowing or kinking, and to maintain the blood supply after suturing. If the opening of the fistula is antimesenteric, the latter reason is not important. The procedure is less successful in cases of regional enteritis, for the fistulas are frequently intramesenteric and there is a chance of including essential vessels in the sutures. This method brought about effective closure in 62.8 per cent of the cases it was employed in.

B. Intraperitoneal procedures. 1. Simple intraperitoneal repair with excision of the fistula. This procedure was performed in 108 cases. With its modifications it is the most common procedure applied, but resection methods have recently gained in use. Incision was made at the operative site (Rigby) or, less frequently, at the remote site (Lockhart-Mummery). The fistula is excised and the intestinal wall closed under direct inspection (Dixon and Deuterman). In this method, as in all intraperitoneal methods, the lesion in the bowel, the adhesions, the blood supply, encroachment on the lumen and any unrecognized internal fistulas can be evaluated. Five to 10 grams of sulfathiazole should be scattered over the repair and in the wound. Placement of drains depends on the induration and soiling. This method was effective in closing the fistula in 69.2 per cent of the cases in which it was attempted.

In 9 additional cases a Witzel enterostomy was performed to protect the repair of the internal opening. The addition of this safeguard is dependent upon the surgeon's sense of caution. The comparative value is difficult to judge because the procedure is employed only in the more difficult cases.

2. Simple repair with plastic operation on the intestine. In 16 cases it was considered advisable to excise a wedge of intestine because of the presence of a lesion in the intestinal wall through which it was not safe to place sutures. Care must be exercised to maintain the blood supply to the antimesenteric border by excising a 45 degree acute angle even if good bowel must be sacrificed. This method was effective in 75 per cent (12) of the 16 cases it was employed in, but the fistula persisted in 1 case (6.3 per cent). There were no deaths in this group. It represents the best results obtained by any method, but the number was not adequate for any definite conclusions. However, it suggests that a common reason for failure in simple closures is that the inverting sutures are placed in diseased intestinal wall.

3. Simple repair with resection of pelvic viscera. This procedure was performed in 32 cases. Most of the cases represent fistulas following incision or attempted excision of a tubo-ovarian abscess, in which a suppurative saccular fistula existed. The procedure was attended with great difficulty in many cases. In some cases dense adhesions made hysterectomy or salpingo-oophorectomy essential in the repair of the fistula. The method was successful in 53.2 per cent of the cases it was performed in.

4. Side-to-side anastomosis without excision of the fistula. This was the definitive operation in 38 cases, of which 58 per cent were successful. It is a partial diversion operation, frequently of palliative nature and not the operation of choice. It cuts off or reduces the amount of feces that passes through the isolated loop of bowel and thus it provides rest for that segment. When there is an intrinsic lesion of the intestine, this is of moderate value as is evidenced by the frequent progress of ulcerative colitis and regional enteritis when the fecal stream is diverted. When the excision of a segment of bowel containing multiple fistulas is beyond the skill of the surgeon it is the safest procedure. In 25 of the more

difficult cases of this series ileocolostomy was performed as the first stage of a more extensive procedure preparatory to the subsequent resection of the terminal portion of the ileum, the cecum and the ascending colon.

In 19 additional cases diversion anastomosis together with the simple excision and closure of the fistula was performed. Detailed discussion of variations of this operation has been given by Keyes and Middleman. They referred to the partial diversion by anastomosis of the proximal and distal segments as a lateral anastomosis. They also described a unilateral exclusion and a bilateral or complete exclusion operation. In the former, the proximal segment is divided, shutting off flow through the affected portion and leaving a blind segment containing the fistula. (This was performed 7 times in this series.) However, reflux discharge may occur in the stump. They favored the bilateral (complete) exclusion operation, in which the side-to-side anastomosis is done in a clean field away from the fistula and both the distal and the proximal loop are severed and closed. From the condition of the patient, the advisability of the immediate resection, subsequent resection or permanent retention of the excluded segment and fistula can be judged. If the closed excluded segment is left in, it will not cause any symptoms. Fistulas connected with segments of the colon usually close spontaneously. Blind segments of ileum secrete small amounts of chyme, but in Rigby's experience even these may close.

5. Resection of the bowel and fistula with anastomosis. This was performed in 97 cases. There were 59.8 per cent of cures with a mortality rate of 8.2 per cent. In many cases added internal fistulas had to be closed simply. In 27 cases the procedure was done in two stages. In an additional 26 cases a proximal Witzel enterostomy or colostomy was performed. This is the operation of choice when there are multiple fistulas and adhesions, or when any plastic repair would cause narrowing of the lumen of the bowel. The cases represented here are mainly those in which there was regional enteritis or ulcerative colitis, or in which there had been numerous previous attempts at repair. Rigby and Keyes and Middleman expressed the opinion that this is a formidable procedure, to be used only in extreme cases. However, despite the fact that this method was applied in cases in which the fistulas were most complex, the mortality rate and percentage of cures compare favorably with those of any other method employed on complex fistulas.

6. Extraperitoneal resection (obstructive resection, Mikulicz). This was performed in 24 cases with a mortality rate of 8.3 per cent. Cures were obtained in 41.7 per cent of the cases. In 4 cases closure of the colonic stoma was followed by a persistent fistula and in 4 others closure of the stoma was not attempted because of disease of the intestinal wall. In this operation the diseased segment of the intestine containing the fistula is exteriorized. The operation is of unquestionable value in lesions of the large intestine and it is a frequently employed method of treatment of such lesions even when no fistula exists. The lesions situated in the sigmoid are commonly accompanied by marked obstruction. Marshall and Lahey, as well as Keyes and Middleman, are enthusiastic about this method and extend its use to the small intestine. They employ it in cases of fistula resulting from regional enteritis. However, closure of the stoma in the small intestine is attended with greater difficulty than closure of a colonic stoma and care of an enteric stoma is more annoying to the patient than care of a colonic stoma.

7. Other procedures. Colostomy alone was performed in 14 cases and ileostomy alone was performed in 4 cases. The rate of cure is small (28.6 per cent for colostomy) but the procedure is indicated when the patient's condition is too poor to allow a more involved operation. In 7 cases the only procedure that could be done was drainage of an intra-abdominal abscess. The operation terminated in simple exploration in 6 cases. Appendectomy was the only procedure in 5 cases. The results of these procedures are not quoted separately because they were palliative and not directed at the cure of the fistula.

Deaths within 1 year after operation are given in all the tables even if the fistula was closed at that time. In most cases they are

due to the basic lesions such as chronic ulcerative colitis, diverticulitis, regional enteritis or pelvic abscess. While operation for repair of the fistula frequently involves removal or isolation of a large part of the diseased segment of intestine, it is not primarily directed at the cure of the basic lesion. In cases in which the patient died of nonrelated disease despite successful closure of the fistula, a further group of cases is removed from the total of successful operations because there was inadequate time to judge whether the closure of the fistula was successful.

C. General principles. From the foregoing discussion it can be seen that the surgeon must employ ingenuity in the selection of the type of procedure to be applied in each case. Lip fistulas in general can be closed by extraperitoneal procedures. Simple tubular fistulas after appendectomy yield good results with simple intraperitoneal closures. Preservation of the blood supply and diameter of the intestinal lumen is of great concern in the cure of multiple complex fistulas. Fistulas originating in granulomatous lesions of the ileum, cecum or colon require resection. Suppurative saccular fistulas present great technical difficulties. Greater safety and a cleaner surgical procedure can be secured by the preliminary performance of ileostomy or colostomy. After a suitable period of rest, the intestine, abscess cavity, and fistula can be resected more leisurely. Study of the histories shows that otherwise these patients are subjected to repeated futile procedures, each in the face of denser adhesions, and in some cases all that can be done is drainage of the abscess. The poorest results were obtained in cases of the less common and miscellaneous group (Table VI) because the lesion involved provided a formidable threat to life on its own account.

The intraperitoneal use of 5 to 10 grams of sulfathiazole (or sulfanilamide) has dramatically reduced the incidence of postoperative peritonitis. Because of this the use of intraperitoneal antiperitonitis vaccine as an added precaution has diminished. The patients suffering from fistula already have a high degree of immunity. The greater security afforded by sulfonamide therapy will undoubtedly increase the use of the more extensive resection methods. Examination of Table XVI will show the greater number of postoperative complications attendant upon side-to-side anastomoses.

It is further suggested that the omentum, when long enough, be brought down to cover the bowel just before closure of the abdominal wall. It is believed that frequently the first step in postoperative recurrence of a fecal fistula after closure is the adhesion of the intestine to the site of the abdominal incision. While there is some question as to whether the omentum stays where it is placed, and it usually finds its way to the suture line in the bowel, the procedure is logical and takes but a few seconds. The use of drains is usually the product of the surgeon's training, experience, and sense of caution. In this series, the peritoneal cavity was drained in less than half the cases. With the use of sulfonamide drugs in the prevention of spreading infection, the employment of drains will become less extensive. In many cases in which anastomosis is performed in the colon, benefit will be derived from dilatation or posterior cautery section of the anal sphincter (C. H. Mayo) in the prevention of gas or fecal retention.

Postoperative care. The balance of fluids and electrolytes is maintained by intravenously and subcutaneously administered solutions. When ileostomy has been performed, gentle suction may be begun immediately. Administration of nonresidue fluids by mouth is begun gradually and by the 4th day a full nonresidue liquid diet may be given in most cases. By the 10th day the majority of the patients are on a smooth soft diet. Oral hygiene is maintained by the chewing of slices of orange or gum. Mineral oil may be given on the 4th postoperative day. Thrombophlebitis is guarded against by suitable exercises in bed. Deep breathing is encouraged. The indications for sulfonamide therapy are the same as in any other intestinal surgical procedure. The postoperative use of succinylsulfathiazole is now the subject of carefully controlled study. The operative mortality rate in this series was 8.1 per cent (33 deaths among 408 patients). The incidence of postoperative complications for each type of operation is presented in Table XVI.

SUMMARY

A review of the literature on fecal fistula is presented with a discussion of the classification, incidence, and etiology. The early history is closely associated with the literature on appendicitis. Five hundred and ninety patients who had fecal fistula registered at the Mayo Clinic in a 12 year period. Of these, 408 came to operation. The remaining 182 did not undergo operation because of an inadequate trial on conservative therapy, extensive malignant lesions, the decision of the patient or medical contraindications.

The records of the 408 surgically treated patients were studied in detail. From this group 50 cases were selected in which routine pathologic diagnosis of the fistula did not give any indication of the cause of the persistence of the fistula. They were subjected to minute examination of repeated sections at various levels. This provided material for the descriptive pathologic anatomy of fecal fistula. The sections were studied as an organized tissue. Suggestions were derived for a discussion of the factors which tend to cause persistence of the fistulas. The initial causes of fecal fistulas have been discussed repeatedly and the subject is reviewed here.

In the majority of the cases active intestinal lesions, such as regional enteritis or the presence of some granuloma-stimulating microscopic foreign substance, such as cotton fibers, talc, petrolatum, or lycopodium, were found. In some cases the defect in the intestine was too large to permit spontaneous closure without reduction of the intestinal lumen. It is maintained that the persistence of fistulas after appendectomy for acute appendicitis is due to an ulcerative or granulomatous lesion of the region, an abscess cavity, gangrene, or constriction of the intestine below the fistula. Fistulas resulting simply from the pressure of drains, misplaced sutures, the nicking of the intestine, inversion of the appendiceal stump or failure to invert it will heal spontaneously. Persistence of the fistula is evidence of an inherent lesion of the intestinal wall or a microscopic or macroscopic foreign substance. These conclusions are drawn *post hoc*, since in most of the cases the initial operations were performed elsewhere.

The presence of foreign body giant cells laden with small cotton fibers in the wall of persistent fistulas suggests the danger of the vigorous swabbing, grasping, and packing with dry gauze so widely practiced. The lint left behind on the delicate peritoneal surface is visible on careful inspection during an operation. Although cotton suture itself may not arouse much of a reaction, finely divided lint plus pressure or brushing injury to the peritoneum stimulates a proliferative fibrous reaction with the formation of fine adhesions. Combined with the formation of a fistula this rather minor reaction is enough to cause persistence of a fistula otherwise predisposed to heal spontaneously. Similar proliferations are produced by talc, petrolatum, or lycopodium. The stability of the tract containing crystals of talc is so marked, in that the fibrous tissue of the tract has such a well organized vascular pattern, that it suggests the use of talc when an intentional attempt is made to establish a persistent fistula, such as in work on the common duct or when well vascularized adhesions are sought.

The methods and importance of the diagnosis of fecal fistulas are discussed. The importance of an adequate trial at spontaneous recovery is stressed. The methods of operative treatment are outlined and the postoperative results analyzed. The operative mortality rate was 8.1 per cent. In 64 cases (15.7 per cent) the fistula persisted after attempt at repair. The postoperative complications, rate of persistence and mortality rate for each lesion, type of fistula, and operative procedure are presented. Preoperative and postoperative care and the adjustment of the operation to the case are discussed. Recent advances, such as the use of sulfonamide drugs, are presented.

REFERENCES

1. AMYAND, CLAUDIUS. Quoted by Deaver, J. B.: Appendicitis; its History, Anatomy, Clinical Aetiology, Pathology, Symptomatology, Diagnosis, Prognosis, Treatment, Technic of Operation, Complications and Sequels. 4th ed., pp. 14 and 30. Philadelphia: P. Blakiston's Sons & Co., 1913.
2. ARETAEUS. The Extant Works of Aretaeus the Cappadocian. pp. 241–289. (Translated by Francis Adams.) London: The Sydenham Society, 1856.
3. BANNICK, E. G. Proc. Mayo Clin., 1934, 9: 99.
4. BARTH, ARTHUR. Deut. med. Wschr., 1890, 16: 742.

5. Bright and Addison. Quoted by Kelly, H. A., and Hurdon, E.
6. Brown, K. T. S. Barth. Hosp. Rep., 1941, 74: 201.
7. Coffey, R. C. Ann. Surg., 1907, 45: 827.
8. Colp, Ralph. Ann. Surg., 1926, 84: 837.
9. Copeland, Thomas. Tr. Med. Chir. Soc. Edinburgh, 1812, 3: 191.
10. Deaver, J. B. Ann. Surg., 1926, 83: 782.
11. Dixon, C. F., and Deuterman, J. L. J. Am. M. Ass., 1938, 111: 2095.
12. Duley, Wade. Am. J. Surg., 1942, n.s. 58: 40.
13. Dupuytren. Quoted by Kelly, H. A., and Hurdon, E.
14. Eliot, Ellsworth, Jr. Ann. Surg., 1927, 86: 406.
15. Erdmann, J. F. Proc. Internat. Assemb. Inter-State Post-Grad. M. A. North America, 1931, 6: 243.
16. Fitz, R. H. Am. J. M. Sc., 1886, 92: 321; Boston M. & S. J., 1886, 115: 13.
17. Forgue, Émile. Precis de pathologie externe. 9th ed., vol. 2, pp. 645–649. Paris: G. Doin & Cie, 1935.
18. Fowler, G. R. Ann. Surg., 1894, 19: 4, 146, 327, 475.
19. Idem. A treatise on appendicitis. Philadelphia: J. B. Lippincott Co., 1894.
20. Gibney, V. P. Tr. N. York Path. Soc., 1877, 2: 86.
21. Gibson, C. L., and Sherrill, W. P. Am. J. Surg., 1926, 40: 7.
22. Ginzburg, L. Surgery, 1940, 7: 515.
23. Grodinsky, Manuel, and Rubnitz, A. S. Surg. Gyn. Obst., 1941, 73: 345.
24. Haggard, W. D. Ann. Surg., 1918, 68: 272.
25. Heineck, A. P. Illinois M. J., 1923, 43: 245.
26. Idem. Delaware State M. J., 1934, 6: 247.
27. Hinglais, Manuel. Internat. Clin., 1921, 3:59.
28. Judd, E. S. Quoted by Carman, R. D. and Miller, Albert: The Roentgen Diagnosis of Diseases of the Alimentary Canal. Philadelphia: W. B. Saunders Co., 1917.
29. Kelly, H. A., and Hurdon, E. The Vermiform Appendix and its Diseases. Pp. 674–681. Philadelphia: W. B. Saunders Co., 1905.
30. Keyes, E. L., and Middleman, I. C. Surg. Gyn. Obst., 1941, 72: 237.
31. Lewis, Dean, and Penick, R. M. Internat. Clin., 1933, 1: 111.
32. Lockhart-Mummery, P. Surg. Gyn. Obst., 1919, 28: 312.
33. MacLaren, Archibald. J. Lancet, 1918, 38: 185.
34. Marshall, S. F., and Lahey, F. H. N. England J. M., 1938, 218: 211.
35. Mayo, C. W., and Schlicke, C. P. Ann. Surg., 1941, 114: 1011.
36. Meriwether, L. S. Proc. Mayo Clin., 1934, 9: 95.
37. Mikulicz, J. von, and Kausch, W. In Bergmann, E. von, Bruns, P. von, and Mikulicz, J. von: A System of Practical Surgery. Vol. 4, pp. 283–290. (Translated by Bull, W. T., Foote, E. M., Flint, C. P. and Martin, Walton.) New York: Lea Brothers & Co., 1904.
38. Muehsam, Richard. Mitt. Grenzgeb. Med. Chir., 1900, 5: 111.
39. Ibid., 1903, 11: 284.
40. Murphy, J. B. Surg. Clin. John B. Murphy, 1915, 4: 757.
41. Pfeifer, J. L., and O'Connell, W. J. Bull. Am. Coll. Surgeons, 1931, 15: 30.
42. Pool, T. L., and Miller, J. M. Proc. Mayo Clin., 1940, 15: 399.
43. Porter, M. F. Am. J. M. Sc., 1893, 106: 649.
44. Ramsey, T. L., and Douglass, F. M. J. Internat. Coll. Surgeons, 1940, 3: 3.
45. Rankin, F. W., and Gorder, A. C. Quoted by Rankin, F. W., Bargen, J. A., and Buie, L. A.
46. Rankin, F. W., Bargen, J. A., and Buie, L. A. The Colon, Rectum and Anus. Pp. 346–358. Philadelphia: W. B. Saunders Co., 1932.
47. Ransom, H. K. Am. J. Surg., 1942, 56: 102.
48. Ray, B. S. N. York State J. M., 1938, 38: 412.
49. Rigby, H. M. Clin. J., Lond., 1911, 38: 289.
50. Rowntree, C. Arch. Middlesex Hosp., 1909, 17: 66.
51. Saracenus. Quoted by Deaver, J. B.: Appendicitis; its History, Anatomy, Clinical Aetiology, Pathology, Symptomatology, Diagnosis, Prognosis, Treatment, Technic of Operation, Complications and Sequels. 4th ed., p. 12. Philadelphia: P. Blakiston's Son & Co., 1913.
52. Schlicke, C. P., and Dixon, C. F. Proc., Mayo Clin., 1940, 15: 409.
53. Senn, Nicholas. The Etiology, Pathology and Treatment of Intestinal Fistula and Artificial Anus. Surgical Monographs, vol. 2, no. 3, 27 pp. Philadelphia: Wm. J. Dornan, 1886.
54. Short, A. R. Lancet, Lond., 1907, 2: 760.
55. Smith, J. G. Abdominal Surgery. 5th ed., vol. 1, p. 146; vol. 2, p. 727. Philadelphia: P. Blakiston, Son & Co., 1896.
56. Warren, Richard, and Miller, R. H. N. England J. M., 1942, 226: 589.

THE EFFECT OF CERTAIN DRUGS ON THE MOTILITY OF THE JEJUNOILEUM IN NORMAL MAN

FERNANDO HUIDOBRO, M.D., ENRIQUE MONTERO, M.D., and FRANCISCO CUEVAS,
Santiago, Chile

INTESTINAL movements in normal man have been studied by means of the x-ray and the kymograph to determine the reaction of the intestine, especially the colon, when a system of balloons connected with a recording device is introduced into a colostomy. The action of several drugs has also been studied by the same method.

Aside from radiologic observations, the motility of, and pharmaco dynamics on, the jejunoileum are little known. Orr and Carlson (1926), Dvorack and collaborators (1931), Abbott and Pendergrass (1936), and Ingelfinger and Abbott (1940) studied the action of morphine by means of intubation. Elson and Drossner observed the effects of atropine, belladonna, benzedrine, and pitressin by the same method (Elson, Glenn, and Drossner, 1939). Forster studied the effects of morphine (1938) and of morphine and atropine (1940) on the longitudinal and circular muscle fibers of an exteriorized loop of small intestine. By means of a system of balloons introduced into an ileostomy, Guthrie and Bargen (1936) observed the effects of pitressin, physostigmine, peristaltine, and acetylcholine, on the small intestine. In the same way Adler, Atkinson, and Ivy (1942) studied the action of morphine and dilaudid, and Schwartz, Reingold, and Necheles (1942), that of prostigmine.

The object of the present work is to determine the action of amyl nitrite, glyceryl trinitrate, theophylline ethylenediamine (cardiomin Collier), methyl octenylamine (octinum Knoll), and diphenyl diethylaminoethanol hydrochloride (trasentin Ciba), and to study more thoroughly the effect of pitressin, prostigmine, morphine, and atropine, on the jejunoileum of normal man.

From the Department of Pharmacology and Biochemistry of the Catholic University of Chile and the Department of Gastroenterology of the Clinical Hospital of the Catholic University of Chile, Santiago, Chile.

METHODS

The studies were carried out in 11 male volunteers who presented no clinical evidence of digestive disease. Their ages ranged between 23 and 55 years. One subject was studied twice.

After 10 hours of fast, the subjects swallowed the Miller-Abbott tube (1934) until its tip lay 2½ to 4½ feet below the pylorus. The presence of the tip in the small intestine was checked by x-ray. At the end of the study the position of the tip in the ileum was again determined by x-ray. The end of the tube connected the rubber balloon at the tip with a Marey tambour. A pressure of 25 centimeters of water (Ingelfinger and Abbott, 1940) was applied to the apparatus. By a separate opening in the tube it was possible to remove fluid which accumulated above the balloon.

When the tip had reached the duodenum, the subject drank 250 cubic centimeters of milk; 2 hours before the tracing was started he took 300 grams of clear soup. While the tracing was being made the subject lay motionless on his back.

The kymographic record was begun at least 15 minutes before the administration of drugs. In each subject the effects of several drugs were studied serially; the complete disappearance of the effects of the previous drug was always awaited before a new one was given.

RESULTS

A. Intestinal motility. The movements recorded from the use of a balloon subjected to a pressure of 25 centimeters of water are very irregular. They consist of small (Fig. 1), medium (Fig. 1), and large waves (Figs. 2, 6a, and 8a). The small waves have a frequency of 5 to 10 per minute, the medium ones, 2 to 3 per minute, and the large ones, once per 1 to 3 minutes.

5. BRIGHT and ADDISON. Quoted by Kelly, H. A., and Hurdon, E.
6. BROWN, K. T. S. Barth. Hosp. Rep., 1941, 74: 201.
7. COFFEY, R. C. Ann. Surg., 1907, 45: 827.
8. COLP, RALPH. Ann. Surg., 1926, 84: 837.
9. COPELAND, THOMAS. Tr. Med. Chir. Soc. Edinburgh, 1812, 3: 191.
10. DEAVER, J. B. Ann. Surg., 1926, 83: 782.
11. DIXON, C. F., and DEUTERMAN, J. L. J. Am. M. Ass., 1938, 111: 2095.
12. DULEY, WADE. Am. J. Surg., 1942, n.s. 58: 40.
13. DUPUYTREN. Quoted by Kelly, H. A., and Hurdon, E.
14. ELIOT, ELLSWORTH, JR. Ann. Surg., 1927, 86: 406.
15. ERDMANN, J. F. Proc. Internat. Assemb. Inter-State Post-Grad. M. A. North America, 1931, 6: 243.
16. FITZ, R. H. Am. J. M. Sc., 1886, 92: 321; Boston M. & S. J., 1886, 115: 13.
17. FORGUE, ÉMILE. Precis de pathologie externe. 9th ed., vol. 2, pp. 645–649. Paris: G. Doin & Cie, 1935.
18. FOWLER, G. R. Ann. Surg., 1894, 19: 4, 146, 327, 475.
19. Idem. A treatise on appendicitis. Philadelphia: J. B. Lippincott Co., 1894.
20. GIBNEY, V. P. Tr. N. York Path. Soc., 1877, 2: 86.
21. GIBSON, C. L., and SHERRILL, W. P. Am. J. Surg., 1926, 40: 7.
22. GINZBURG, L. Surgery, 1940, 7: 515.
23. GRODINSKY, MANUEL, and RUBNITZ, A. S. Surg. Gyn. Obst., 1941, 73: 345.
24. HAGGARD, W. D. Ann. Surg., 1918, 68: 272.
25. HEINECK, A. P. Illinois M. J., 1923, 43: 245.
26. Idem. Delaware State M. J., 1934, 6: 247.
27. HINGLAIS, MANUEL. Internat. Clin., 1921, 3:59.
28. JUDD, E. S. Quoted by Carman, R. D. and Miller, Albert: The Roentgen Diagnosis of Diseases of the Alimentary Canal. Philadelphia: W. B. Saunders Co., 1917.
29. KELLY, H. A., and HURDON, E. The Vermiform Appendix and its Diseases. Pp. 674–681. Philadelphia: W. B. Saunders Co., 1905.
30. KEYES, E. L., and MIDDLEMAN, I. C. Surg. Gyn. Obst., 1941, 72: 237.
31. LEWIS, DEAN, and PENICK, R. M. Internat. Clin., 1933, 1: 111.
32. LOCKHART-MUMMERY, P. Surg. Gyn. Obst., 1919, 28: 312.
33. MACLAREN, ARCHIBALD. J. Lancet, 1918, 38: 185.
34. MARSHALL, S. F., and LAHEY, F. H. N. England J. M., 1938, 218: 211.
35. MAYO, C. W., and SCHLICKE, C. P. Ann. Surg., 1941, 114: 1011.
36. MERIWETHER, L. S. Proc. Mayo Clin., 1934, 9: 95.
37. MIKULICZ, J. VON, and KAUSCH, W. In Bergmann, E. von, Bruns, P. von, and Mikulicz, J. von: A System of Practical Surgery. Vol. 4, pp. 283–290. (Translated by Bull, W. T., Foote, E. M., Flint, C. P. and Martin, Walton.) New York: Lea Brothers & Co., 1904.
38. MUEHSAM, RICHARD. Mitt. Grenzgeb. Med. Chir., 1900, 5: 111.
39. Ibid., 1903, 11: 284.
40. MURPHY, J. B. Surg. Clin. John B. Murphy, 1915, 4: 757.
41. PFEIFER, J. L., and O'CONNELL, W. J. Bull. Am. Coll. Surgeons, 1931, 15: 30.
42. POOL, T. L., and MILLER, J. M. Proc. Mayo Clin., 1940, 15: 399.
43. PORTER, M. F. Am. J. M. Sc., 1893, 106: 649.
44. RAMSEY, T. L., and DOUGLASS, F. M. J. Internat. Coll. Surgeons, 1940, 3: 3.
45. RANKIN, F. W., and GORDER, A. C. Quoted by Rankin, F. W., Bargen, J. A., and Buie, L. A.
46. RANKIN, F. W., BARGEN, J. A., and BUIE, L. A. The Colon, Rectum and Anus. Pp. 346–358. Philadelphia: W. B. Saunders Co., 1932.
47. RANSOM, H. K. Am. J. Surg., 1942, 56: 102.
48. RAY, B. S. N. York State J. M., 1938, 38: 412.
49. RIGBY, H. M. Clin. J., Lond., 1911, 38: 289.
50. ROWNTREE, C. Arch. Middlesex Hosp., 1909, 17: 66.
51. SARACENUS. Quoted by Deaver, J. B.: Appendicitis; its History, Anatomy, Clinical Aetiology, Pathology, Symptomatology, Diagnosis, Prognosis, Treatment, Technic of Operation, Complications and Sequels. 4th ed., p. 12. Philadelphia: P. Blakiston's Son & Co., 1913.
52. SCHLICKE, C. P., and DIXON, C. F. Proc., Mayo Clin., 1940, 15: 409.
53. SENN, NICHOLAS. The Etiology, Pathology and Treatment of Intestinal Fistula and Artificial Anus. Surgical Monographs, vol. 2, no. 3, 27 pp. Philadelphia: Wm. J. Dornan, 1886.
54. SHORT, A. R. Lancet, Lond., 1907, 2: 760.
55. SMITH, J. G. Abdominal Surgery. 5th ed., vol. 1, p. 146; vol. 2, p. 727. Philadelphia: P. Blakiston, Son & Co., 1896.
56. WARREN, RICHARD, and MILLER, R. H. N. England J. M., 1942, 226: 589.

THE EFFECT OF CERTAIN DRUGS ON THE MOTILITY OF THE JEJUNOILEUM IN NORMAL MAN

FERNANDO HUIDOBRO, M.D., ENRIQUE MONTERO, M.D., and FRANCISCO CUEVAS,
Santiago, Chile

INTESTINAL movements in normal man have been studied by means of the x-ray and the kymograph to determine the reaction of the intestine, especially the colon, when a system of balloons connected with a recording device is introduced into a colostomy. The action of several drugs has also been studied by the same method.

Aside from radiologic observations, the motility of, and pharmaco dynamics on, the jejunoileum are little known. Orr and Carlson (1926), Dvorack and collaborators (1931), Abbott and Pendergrass (1936), and Ingelfinger and Abbott (1940) studied the action of morphine by means of intubation. Elson and Drossner observed the effects of atropine, belladonna, benzedrine, and pitressin by the same method (Elson, Glenn, and Drossner, 1939). Forster studied the effects of morphine (1938) and of morphine and atropine (1940) on the longitudinal and circular muscle fibers of an exteriorized loop of small intestine. By means of a system of balloons introduced into an ileostomy, Guthrie and Bargen (1936) observed the effects of pitressin, physostigmine, peristaltine, and acetylcholine, on the small intestine. In the same way Adler, Atkinson, and Ivy (1942) studied the action of morphine and dilaudid, and Schwartz, Reingold, and Necheles (1942), that of prostigmine.

The object of the present work is to determine the action of amyl nitrite, glyceryl trinitrate, theophylline ethylenediamine (cardiomin Collier), methyl octenylamine (octinum Knoll), and diphenyl diethylaminoethanol hydrochloride (trasentin Ciba), and to study more thoroughly the effect of pitressin, prostigmine, morphine, and atropine, on the jejunoileum of normal man.

From the Department of Pharmacology and Biochemistry of the Catholic University of Chile and the Department of Gastroenterology of the Clinical Hospital of the Catholic University of Chile, Santiago, Chile.

METHODS

The studies were carried out in 11 male volunteers who presented no clinical evidence of digestive disease. Their ages ranged between 23 and 55 years. One subject was studied twice.

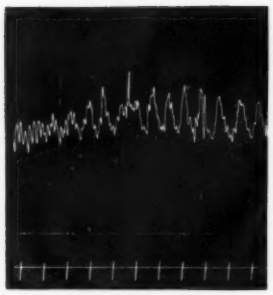
After 10 hours of fast, the subjects swallowed the Miller-Abbott tube (1934) until its tip lay 2½ to 4½ feet below the pylorus. The presence of the tip in the small intestine was checked by x-ray. At the end of the study the position of the tip in the ileum was again determined by x-ray. The end of the tube connected the rubber balloon at the tip with a Marey tambour. A pressure of 25 centimeters of water (Ingelfinger and Abbott, 1940) was applied to the apparatus. By a separate opening in the tube it was possible to remove fluid which accumulated above the balloon.

When the tip had reached the duodenum, the subject drank 250 cubic centimeters of milk; 2 hours before the tracing was started he took 300 grams of clear soup. While the tracing was being made the subject lay motionless on his back.

The kymographic record was begun at least 15 minutes before the administration of drugs. In each subject the effects of several drugs were studied serially; the complete disappearance of the effects of the previous drug was always awaited before a new one was given.

RESULTS

A. Intestinal motility. The movements recorded from the use of a balloon subjected to a pressure of 25 centimeters of water are very irregular. They consist of small (Fig. 1), medium (Fig. 1), and large waves (Figs. 2, 6a, and 8a). The small waves have a frequency of 5 to 10 per minute, the medium ones, 2 to 3 per minute, and the large ones, once per 1 to 3 minutes.



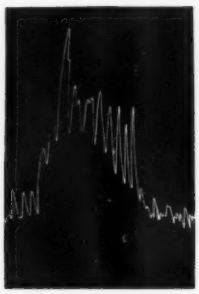


Fig. 1, left. Intestinal motility J. M., aged 45 years. Balloon was 2½ feet below the pylorus. Intestinal movements at left of figure are type I; those at right are type II. (In this and subsequent figures time is marked in 1 minute intervals; in the originals the drum moved 6 millimeters per minute. Balloon pressure, 25 centimeters of water.)

Fig. 2. Intestinal motility in E. M., aged 26 years. Balloon was 3 feet below the pylorus. Type III motility.

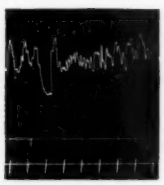
Among these waves may be distinguished the three types of motility described by Templeton and Lawson (1931) and by Adler, Atkinson, and Ivy (1941 and 1942), for the large intestine of dog and of man, namely: types I, II, and III (Figs. 1, 2, 5a, 6a, and 8a).

In our 12 observations the 3 types of motility were combined in 6 persons; types I and III were combined in 3 cases, types I and II were associated in 2 cases, and a single type, type I, appeared in only 1 person. Type I can be said to predominate, having been present in all 12 cases; next comes type III, in 9 of 12 cases; and finally, type II, in 7 of 12 cases.

In the normal individual therefore, the movements of the jejunoileum differ from those of the large intestine, in that type II waves predominate in the latter (Adler, Atkinson, and Ivy, 1941). In addition, type III waves of the small intestine last 1 to 3 minutes, as compared to the 5 minutes described for the colon (Adler, Atkinson, and Ivy, 1942).

Effects of Drugs

B. Amyl nitrite. Amyl nitrite was inhaled until flushing appeared. In every case studied (4 cases) there occurred a marked fall in intestinal tone and disappearance of motility (Fig. 3), or at least a considerable decrease in the volume of the contractions. This phenomenon appeared as soon as the general effects of the nitrite began and lasted about a minute,



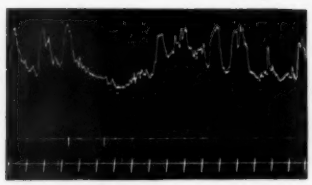


Fig. 3, left. Action of amyl nitrite J. M., aged 45 years. Balloon was 2½ feet below the pylorus. Signal indicates moment of inhalation of amyl nitrite.

Fig. 4. Action of theophylline ethylenediamine in J. M., aged 45 years. Balloon was 2½ feet below the pylorus. Between the two signals, an intravenous injection of 0.24 gram of theophylline ethylenediamine was given.

except that in 1 case the decrease both in tonus and amplitude of contractions lasted 2½ minutes.

Jackman and Bargen (1938) studied the action of this drug on the colon. They also observed a definite decrease in tonus and an absence of contractions. Their results differ from ours in that in their series the effect lasted 3 to 5 minutes and was followed by a slow recovery; in our observations the longest period was 2½ minutes, after which there was rapid recovery to the same type of activity shown previous to the administration of the drug (Fig. 3).

C. Glyceryl trinitrate. Jackman and Bargen (1938), administered 0.6 milligram of nitroglycerine under the tongue and obtained a decrease of tone in the colon lasting 20 to 50 minutes, an action less intense but longer lasting than that following the use of amyl nitrite. We used an alcoholic solution of nitroglycerine (1%) recently prepared. It was administered under the tongue in doses from 3 to 10 drops (0.5 to 1.66 mgm.). No effect was seen in the kymograph records of any of the 4 subjects, despite repeated attempts in each case.

D. Theophylline ethylenediamine. Theophylline ethylenediamine (cardiomine Collier), in doses of 0.24 gram by slow intravenous injection, produced a definite fall in tonus of the ileum in the 4 persons studied, even before the full dose had been injected. The intestinal movements were type I throughout the period of activity of the drug, and in 3 of 4 cases the waves became much smaller (Fig. 4). Four and one-half minutes was the longest period of effectiveness of the drug, and recovery was

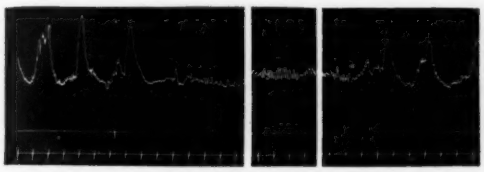


Fig. 5. Action of methyl octenylamine in J. M., aged 45 years. Balloon was 2½ feet below the pylorus. a, left, Signal indicates time of injection of 100 milligrams of methyl octenylamine subcutaneously. Movements prior to injection are type III. b, center, 11 minutes after a; c, right, 11 minutes after b.

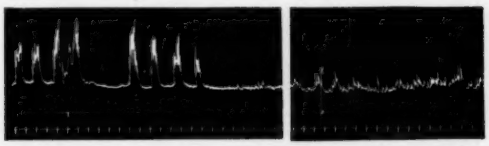


Fig. 6. Action of diphenyl diethylaminoethanol hydrochloride in P. H., aged 55 years. Balloon was 4 feet below the pylorus. a, left, Signal indicates time of subcutaneous injection of 0.075 gram of diphenyl diethylaminoethanol hydrochloride. Movements prior to injection are type III. b, right, 49 minutes after a.

slower than that seen following the use of amyl nitrite.

E. Methyl octenylamine. Methyl octenylamine (octinum Knoll) injected subcutaneously in doses of 100 milligrams produced, in the 4 volunteers studied, a great decrease in the intestinal movements, only small waves of type I variety were noted and at times these disappeared. In 2 cases the tonus fell significantly during the period of action of the drug; in the 3d patient a less distinct fall in tonus was noted, while in the 4th none at all was noted (Fig. 5). The effect of this drug began 5 to 17 minutes after injection and lasted 38 to 66 minutes. Recovery was slow. After the effects of the drug seemed to have worn off, the motility did not return to the type noted before the use of the methyl octenylamine; in general the movements afterward were type I or a combination of types I and II.

In the hands of Atkinson, Adler, and Ivy (1943), octinum injected in doses of 100 milligrams or given by mouth up to 300 milligrams did not change the activity of the large intestine during 2 hours of observation.

F. Diphenyl diethylaminoethanol hydrochloride. This drug (trasentin Ciba), in doses of 0.075 gram given by deep subcutaneous injection, produced effects similar to those of octinum. In the 4 volunteers used, the tonus fell, though not markedly; in 2 the volume of the contractions decreased enormously, so that, as may be seen in Figure 6, the movements almost disappeared. Recovery was slow (Fig. 6), and the rhythm of movement was different from that seen before the drug was given. The action began 3 to 17 minutes after the injection and lasted 88 minutes. In 1 case this drug merely lowered almost imperceptibly the tonus of the intestine; this experiment lasted 75 minutes.

Jackman and Bargen (1938) studied the action on the movements of the large intestine when the drug was given slowly by vein in a dose of 0.05 gram. They observed a decrease in tonus and a decrease but not a disappearance of the wavelike activity. Atkinson, Adler, and Ivy (1943), injecting intramuscularly 50 to 100 milligrams or giving 75 to 225 milligrams by mouth, noted a decrease in tonus and in some cases (35%) a decrease or an absence of the movements of the colon; in 14 per cent of their observations they did not find this decrease. In 1 case in 5, these authors found that trasentin rendered the movements of the large intestine more regularly rhythmic.

G. Pitressin. In 8 volunteers we injected subcutaneously in doses of 4 to 10 units pitressin prepared in the Instituto Bacteriológico de Chile (Hipofisina). These doses produced a clear fall in the base line (Fig. 7) and a change in the peristaltis movements, which became gigantic type II waves. Often a certain rhythm was maintained, or the irregular movements which had preceded the injection became more regular. These gigantic waves coincided with abdominal pains of a colic-like nature; between them there was a relative absence of intestinal motility. Figure 7 exemplifies the action of this drug. The effects began 2½ minutes after subcutaneous injection.

Similar results were obtained by Elson, Glenn, and Drossner (1939). They found decrease of tonus in the jejunum but increase in the ileum. In both segments large waves appeared and the small ones disappeared. In the terminal ileum Guthrie and Bargen (1937)

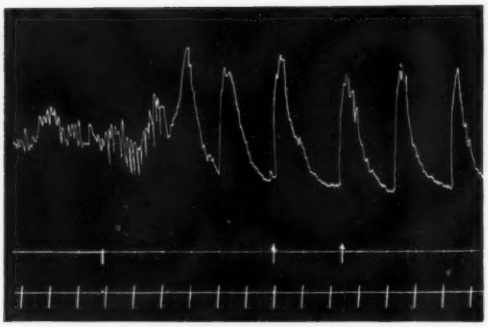


Fig. 7. Action of pitressin in J. M., aged 45 years. Balloon was 2½ feet below the pylorus. Signal indicates time of subcutaneous injection of 5 units of pitressin. Arrows indicate moments at which subject had colic-like abdominal pains.

noted that pitressin produced large waves every 1½ to 3 minutes, beginning 2 minutes after injection and lasting 55 minutes.

The effects of pitressin on the colon are much like those on the ileum (Guthrie and Bargen, 1936; Adler, Atkinson, and Ivy, 1942; Atkinson, Adler, and Ivy, 1943).

H. Prostigmine. Prostigmine (prostigmine methylsulfate, Hoffman La Roche), in doses of 0.5 milligram subcutaneously, produced effects after 13 to 18 minutes which lasted until 80 minutes after the injection. In 3 of 4 volunteers it increased the amplitude of the contractions (Fig. 8). In 1 case of the 4, there was a discrete fall of tonus with no other effect during the 53 minutes of observation. In 1 person in whom the intestinal movements had been type III, the waves became larger and appeared at greater intervals than before the use of the drug.

Schwartz, Reingold, and Necheles (1942) observed an increase in motor activity of the small intestine when this drug was used. Adler, Atkinson, and Ivy (1942) and Atkinson, Adler, and Ivy (1943), using the same dose as we had used, observed the same results as we did in reference to the colon, but the effect was more intense. They saw in all cases an increase in the propulsive and general activity of the large intestine, the effect beginning 20 minutes after the injection of the drug and lasting 1 to 2 hours.

I. Atropine sulfate. One milligram of atropine sulfate injected subcutaneously decreased

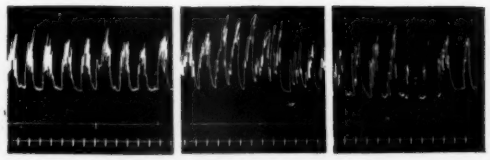


Fig. 8. Action of prostigmine in P. H., aged 55 years. Balloon 4 feet below pylorus. a, left, Signal indicates time of subcutaneous injection 0.5 milligram prostigmine. b, center, 7½ minutes after a; c, 19 minutes after b.

slightly the tonus of the intestine. The waves were smaller, and, if they had been type II or III, they changed to type I. The same dose of atropine injected after pitressin caused the disappearance of the large waves described in section G. Our results agree with those described by Elson and Drossner (1939) in regard to the small intestine. Atropine causes a decrease in tonus of the large intestine (Jackman and Bargen, 1938) and may even cause the spontaneous motor activity to disappear (Atkinson, Adler, and Ivy, 1943).

J. Morphine sulfate. Previous results in reference to the action of morphine sulfate on the small intestine have been contradictory. Orr and Carlson (1926) and Dvorack and collaborators (1931) found that the usual clinical doses of morphine increase the peristaltic activity of the small intestine, but that larger doses (Orr and Carlson, 1926) decrease the activity without changing the frequency of the contractions. On the other hand Abbott and Pendergrass (1936) observed an increase in the contractions; in addition they describe an increase in tonus and a decrease in amplitude. This effect was followed by a depressor action which lasted several hours and could be the only visible effect in the ileum. Forster (1938 and 1940), using a different technique, confirmed the results of Abbott and Pendergrass (1936) in regard to the action of morphine on tonus and frequency; he also called attention to the suppression of the propulsive activity. Adler, Atkinson, and Ivy (1942) found that morphine, in the majority of cases, increased the tonus and amplitude of the contractions, but that there are cases in which it has no effect or may decrease the tonus. Moreover, Abbott and collaborators (1943) observed a rise of basal intraintestinal pressure by the action of this drug.

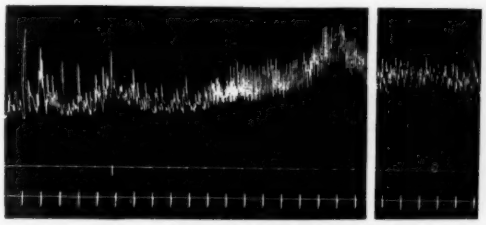


Fig. 9. Action of morphine in P. H., aged 55 years. Balloon was 4 feet below the pylorus. a, left, Signal indicates time of subcutaneous injection of 0.01 gram of morphine sulfate. b, 16 minutes after a.

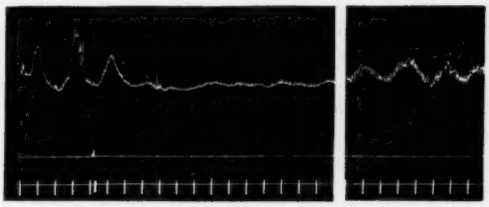


Fig. 10. Action of morphine in F. C., aged 23 years. Balloon was 3 feet below the pylorus. a, left, Signal indicates the time of subcutaneous injection of 0.02 gram of morphine sulfate; b, 20 minutes after a.

Our results do not differ from those recorded by these various authors. In 4 subjects, morphine sulfate in doses of 0.8 to 2 centigrams injected subcutaneously produced a decrease in amplitude of the intestinal movements (Figs. 9 and 10) until they almost disappear (Fig. 9). The action begins between 3 and 8 minutes after the injection. In half of our cases morphine decreased the tonus and, in the other half, increased it (Fig. 10).

In the large intestine, Bargen and Jackman (1939) demonstrated an increase in tonus, peristalsis, and amplitude of contraction. Adler, Atkinson, and Ivy (1943) described, in the majority of their experiments, an increase in the nonpropulsive activity and of the tonus, with loss of the propulsive activity. In one of the segments of the colon they found a decrease in tonus and an increase in the frequency of contraction. The same authors had published similar results the previous year.

ANALYSIS OF STUDY

The method described herein is the only one available which permits the graphic study of intestinal movements in a normal person. It is far from ideal, however. The type of movement depends on the pressure in the system (Welch, 1937); to this factor we attribute the absence of periods of inactivity of the small intestine which are demonstrated by means of other techniques (Forster, 1940). Moreover, one cannot distinguish between the types of activity which are contributed by the circular and by the longitudinal muscle fibers.

Another disadvantage of the method is the difficulty of keeping the balloon in the same segment; despite fixation of the external end of the tube, the intestinal end of it may move to a more distal segment because of the activity of the intestine during the period of the study (about 5 hours). Aside from this, the lower segments exhibit less motility (law of intestinal gradient of Alvarez, 1940).

The pressure in the balloon depends not only on the activity of the intestine itself, but also on changes of intra-abdominal pressure due to muscular contractions in the abdominal region, conditions which impede the registration of intestinal movements during vomiting or other conditions producing an increase of intra-abdominal pressure.

All our subjects were given a small meal before the tracings were made, partly to keep the intestine as near to the normal state as possible, and partly to prevent fatigue of the subjects due to the long duration of the experiments (8 to 10 hours) and the action of the various drugs which were used on them.

Templeton and Lawson (1931) and Adler, Atkinson, and Ivy (1941 and 1942) described various types of movements in the intestine of dog and man. According to them, type I corresponds to nonpropulsive intestinal activity; and type II corresponds to a wave of activity usually propulsive, the predominant type of movement of the colon. Contrary to Adler, Atkinson, and Ivy (1941 and 1942) we have seen type I in the jejunoileum of the normal man more often than type II. If the latter wave represented propulsive activity of the intestine it should be observed more frequently in the small intestine, for this type of motility is more characteristic of this segment of the intestine (Alvarez, 1940).

Comparing the action on the small intestine with those observed on the colon of the various drugs studied as reported by other authors (see "Results"), it is seen that these two parts of the gut react very similarly. The large intestine, however, would seem to be more sensitive to these drugs than the small intestine as shown by the following comparisons: absence of effect of nitroglycerine on the ileum (section C), compared to the intense inhibition in the colon as described by Jackman and Bargen (1938); greater duration of the effect of amyl nitrite on the colon (Jackman and Bargen, 1938); complete inhibition of the activity of the colon by atropine (Atkinson, Adler, and Ivy, 1943) and by diphenyl diethylaminoethanol hydrochloride; and greater increase of tonus in the large intestine than observed by us in the small intestine by morphine (Section J). Considering the importance of these facts it would be very interesting to study them in more detail.

SUMMARY

The movements of the jejunoileum and the action of drugs commonly indicated for use in relation to this part of the digestive tract were studied in 11 normal volunteers without evidence of digestive disturbances. The movements were recorded on a kymograph from a Marey tambour connected with the balloon of a Miller-Abbott tube introduced into the intestine 2½ to 4½ feet below the pylorus.

1. The intestinal movements were irregular but might be grouped in three types: types I, II, and III (Figs. 1, 2, 5a, 6a, and 8a). Type I was the most frequent, type III next, and type II the least frequent (section A).

2. Amyl nitrite decreased markedly the intestinal movements and the tonus of the jejunoileum. This effect was brief (section B and Fig. 3).

3. Nitroglycerine did not affect intestinal movements.

4. Theophylline ethylenediamine acted like amyl nitrite but less intensely and for a longer time (section D and Fig. 4).

5. Methyl octenylamine and diphenyl diethylaminoethanol hydrochloride decreased markedly the amplitude of the intestinal movements for more than 60 minutes and tended to decrease the tonus (sections E and F and Figs. 5 and 6).

6. Pitressin and prostigmine increased the spontaneous motility of the small intestine; the effect of the former was more intense and more constant than that of the latter (sections G and H and Figs. 7 and 8).

7. Atropine sulfate and morphine sulfate decreased the motor activity of the jejunoileum. The former may cause the exaggerated motility produced by pitressin to disappear, and the latter, in a large dose, may cause the intestinal movements almost to disappear and slightly increase the tonus (sections I and J and Figs. 9 and 10).

REFERENCES

1. Abbott, W. O., Hartline, H. K., Hervey, J. P., Ingelfinger, F. J., Rawson, A. J., and Zetzel, L. J. Clin. Invest., 1943, 22: 225.
2. Abbott, W. O., and Pendergrass, E. P. Surg. Gyn. Obst., Internat. Abstr. Surg., 1936, 63: 232.
3. Adler, H. F., Atkinson, A. J., and Ivy, A. C. Am. J. Digest. Dis., 1941, 8: 197.
4. Idem. Surg. Gyn. Obst., 1942, 74: 809.
5. Atkinson, A. J., Adler, H. F., and Ivy, A. C. J. Am. M. Ass., 1943, 121: 646.
6. Alvarez, W. C. An Introduction to Gastro-Enterology. New York: Paul B. Hoeber Inc., 1940.
7. Bargen, J. A., and Jackman, R. J. Surg. Gyn. Obst. 1939, 68: 749.
8. Dvorack, H. G., Carlson, H. A., Herickson, T. C., Smith, V. D., and Wangensteen, O. H. Proc. Soc. Exp. Biol., N. Y., 1931, 28: 434 (cited by 12).
9. Elson, K. A., and Drossner, J. L. Am. J. Digest. Dis., 1939, 6: 589.
10. Elson, K. A., Glenn, P. M., and Drossner, J. L. Am. J. Digest, Dis., 1939, 6: 593.
11. Forster, A. C. Proc. Soc. Exper. Biol., N. Y., 1938, 38: 332.
12. Forster, A. C. Ann. Surg., 1940, 112: 370.
13. Guthrie J. S., and Bargen, J. A. Surg. Gyn. Obst., 1936, 63: 743.
14. Ingelfinger, F. J., and Abbott, W. O. Am. J. Digest. Dis., 1940, 7: 468.
15. Jackman, R. J., and Bargen, J. A. Surg. Gyn. Obst., 1938, 67: 63.
16. Miller, T. G., and Abbott, W. O. Am. J. M. Sc., 1934, 187: 595.
17. Orr, T. B., and Carlson, H. E. Arch. Surg., 1926, 27: 296 (cited by 12).
18. Templeton, R. D., and Lawson, H. Am. J. Physiol., 1931, 96: 667.
19. Schwartz, A. H., Reingold, I., and Necheles, H. Surgery, 1942, 11: 746.
20. Welch, P. B. Am. J. Digest. Dis., 1937, 4: 382.

THE TREATMENT OF WAR WOUNDS AT U. S. NAVAL BASE HOSPITAL NO. 2

JOHN E. PORTER, M.D., F.A.C.S., Captain, Medical Corps, U. S. Navy

IT seems pertinent that certain observations and experiences gained at the first Advance Base Hospital to be established in the South Pacific area from the care and treatment of the wounded during the past 17 months should be presented at this time. We have learned in handling war casualties that dogmatic proposals as to methods of treatment serve only to initiate controversial discussions. By reporting our personal obervations, we believe information may be imparted to others which may favorably influence the care of military casualties in the future.

U. S. Naval Base Hospital No. 2 is situated within 6 hours' flying distance from the front and receives casualties both by ambulance planes and ships. Over 90 per cent of the patients with war wounds were transported by ambulance plane. The elapsed time from the incident of the wound until admission to this hospital has averaged 36 hours, although some patients (local casualties) have been received almost immediately and others have been brought here after an interval of a week or longer. The type of primary and first aid care administered at the front and the time interval elapsing until evacuation to this base have been the important factors in influencing our plan of treatment. Due credit and commendation should be given to skill with which medical officers and hospital corpsmen at the front have rendered this vital and lifesaving service under the most adverse conditions. We have learned that all subsequent treatment is based on two factors: (1) the type of primary care rendered at the front, and (2) the time interval which elapsed between this treatment and the evacuation to this base.

Following the first offensive in the Solomons all patients with war wounds were given first aid care only, that is, hemorrhage was controlled, plasma administered, sulfathiazole dusted locally, and the wounds packed with gauze, battle dressings applied, tetanus booster given and, most importantly, fixation splints applied for immobilization during evacuation by plane. All of the patients in this first group were given sulfathiazole orally. Upon admission to this hospital supportive treatment was continued, x-ray studies were made, and the necessary and indicated operations were performed under optimum conditions. It is interesting to note that during this period, when this hospital received evacuees treated only in the manner described, very few patients developed wound infection. Also, of equal importance, only 1 case of gas bacillus infection was received during this period. Later on, when routine débridement and attempts at primary closure were instituted in the field hospitals at the front, necessarily under adverse conditions, we began to receive with progressive frequency both infected wounds and cases of gas bacillus infection.

All cases were classified in following categories: Class A, convalescent expectancy of less than 90 days; Class C, convalescent expectancy of over 90 days; Class D, permanently disabled for further duty in South Pacific area. Casualties under classification A were returned to duty as soon as practicable. Those patients classified under C and D were evacuated to a hospital ship or an ambulance ship for transfer and further disposition.

When a wounded patient arrives at this hospital, and if he is not in shock, x-ray studies are usually made before he is taken to the operating room. The films will reveal if there are any fractured bones and the locations of either shrapnel fragments or bullets. X-ray studies are not as valuable as one might suppose in recognizing gas bacillus infection as any low speed projectile will carry air into the tissues, particularly if splinters of wood, cloth-

The opinions contained herein are the private ones of the author and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

From the Department of Surgery, U. S. Naval Base Hospital Number Two, Fleet Post Office, San Francisco.

ing, or other foreign bodies precede the projectile. It is important to get a history as to the type of missile which produced the wound, the course, type, and location of the missile. If it is a wound caused by a high velocity bullet, there is not as much destruction of tissue as in a wound caused by shell fragments. The knowledge of the degree of previous shock will inform the surgeon as to the amount of surgery that can be done with safety to the patient. The patients who experienced severe shock after being wounded will not tolerate a long drawn-out operation. Speed, gentleness, and good judgment are the paramount requirements in this type of case.

The skin surrounding the wound is thoroughly cleansed with soap and water, after which the skin border of the wound is excised, care being taken not to remove any more than is necessary. The incision should be large enough, however, to allow free access to the entire wound. All of the devitalized tissue should be removed until bleeding, healthy muscle tissue which contracts when it is pinched with forceps is encountered. All foreign bodies and loose pieces of bone should be removed if possible. In removing the damaged tissue care should be exercised to prevent further damage to the nerves, tendons, and blood vessels or other vital structures. No dead tissue should be left in the wound. All bleeding points should be carefully ligated. The wound is then irrigated with 1:3300 azochloramid solution and from 4 to 12 grams of sulfanilamide crystals are dusted into the wound. The spaces in the wound are obliterated as much as possible without putting tension on the sutures. If a thorough débridement has been accomplished and there is no evidence of infection, primary closure is done.

An attempt has been made to determine whether healing is promoted and the period of disability is lessened by leaving a gunshot wound open or by making a tight closure after a thorough débridement has been made in noninfected wounds. In our experience, each case must be individualized. No hard and fast rule can be made. If a thorough débridement can be effected, sulfanilamide crystals are dusted into the wound, and it is then closed without drainage. Such closure has been possible in about 90 per cent of all cases with primary healing in about 85 per cent of the cases so closed. We believe that these men have been returned to duty many days, or even several weeks, earlier because of the use of primary closure. We also believe that scar tissue formation, with resultant disability from adhesions, has been reduced.

The primary principles in making complete closure are thorough débridement of all necrotic tissue and closure without undue tension. In some cases in which complete closure has been impossible due to tension, as much of the wound as could be readily approximated is closed, while the remainder has been left open. This practice has "saved skin" in many instances. It seems clear that when sutures are removed too soon the wound margins separate and subsequent healing occurs by granulations; thus the original purpose of the primary closure is defeated.

We have followed conservative treatment methods in the management of wounds about the face and in chest wounds. In face wounds we remove only the dead tissues and foreign bodies, saving all the skin possible and not removing any bone unless it is separated from its periosteum. The wound is otherwise treated the same as any other gunshot wound.

In most of the patients with chest wounds admitted to this hospital, the hemorrhage had stopped and the patient was not in severe shock. If open pneumothorax was present a débridement was done, the foreign bodies were removed if possible and the wound was closed in layers without drainage. If there was a perforating wound, with fracturing of the ribs and with portions of the bone driven into the pleural cavity or lung, but without a sucking wound, it was treated conservatively until the patient was in good condition, after which débridement and removal of rib fragments was done. X-ray localization is essential before an attempt is made to remove any foreign bodies from the lung. Most of the patients with punctate entrance and exit wounds, whether due to bullets or small shell fragments, recover without operation. Aspiration was done in those patients who presented any of the following symptoms or signs: (1) hemothorax which filled the entire pleural cavity

on one side; (2) severe pain on inspiration; (3) cyanosis; (4) dyspnea; and (5) shifting of the mediastinum. If, however, the temperature and pulse did not subside, or tended to increase, or if the patient showed an anxious expression, aspiration was done for bacteriological examination of the fluid. All chest wound patients were given large doses of sulfathiazole orally for the first week after entering the hospital. If the temperature were normal at the end of that time, the sulfathiazole was discontinued, but if the temperature remained elevated above 1 degree, the sulfathiazole was continued in smaller doses. Empyema did not develop in any case.

GAS BACILLUS INFECTIONS

We have had 35 cases of gas bacillus infection. All had clinical gas gangrene, confirmed bacteriologically. Four deaths occurred from gas bacillus infection; 3 of the patients who died had thigh wound infection and the 4th had an abdominal wound infection.

All but 2 of the patients who had gas bacillus infection were given Parke-Davis combined gas gangrene antitoxin. A thorough débridement was done in all cases in which gangrene was not present. Amputation was done in cases of gas bacillus infection with thrombosis of the artery and gangrene. All wounds were dusted with sulfanilamide crystals at time of operation, and wounds were packed open with vaseline gauze. Plasma, transfusions, and fluids were given intravenously as indicated.

Gas bacillus infection did not develop in any case in which a thorough débridement was done. All wounds had been dusted with sulfanilamide in the field and most patients had received sulfathiazole by mouth.

Our experiences at this hospital have shown beyond doubt the value of the application of sulfanilamide in the wound and of sulfathiazole by mouth. The drugs should be given directly after the wound occurs and also following débridement. This combination of sulfonamide therapy seems to have prevented the development of infection in contaminated wounds.

TREATMENT OF COMPOUND FRACTURES

Transportation. Patients were transported to this hospital by Marine and Army Air transport planes. Transportation to and from air fields was by standard Army and Navy ambulances. In the latter campaigns, as the line of battle went northward, transportation from the outlying islands was by landing ship, tank craft, from the battle line to a developed air field where air transport was available. In the Guadalcanal campaign transportation time averaged 6 to 8 hours; most casualties arrived within 24 to 36 hours from the time they were wounded. In the New Georgia campaign transportation time averaged 4 to 7 days from time of wounding. Distances varied from 500 to 1000 miles by air transport. A few casualties were taken directly from ships, which had received them in transfer from warships at the scene of battle. Air transport of more than 7 hours was too strenuous even for patients with slight wounds. No ill effects from altitude were noted on any fracture patients even after severe hemorrhage had occurred. Most patients on admission were worn out from long transportation, the lapse of time, and pain. They were usually hungry because messing facilities were often inadequate, particularly during the early phases of the Guadalcanal campaign. Most men were dehydrated.

Splinting. The majority of patients with fractures of the long bones were received with the fracture fixed in a Thomas or Keller, hinged, half-ring (Army) splint. In many of the earlier cases traction hitches applied over the shoe or foot had caused deep pressure sores over the dorsum of the foot and the tendo achillis. It is believed that adhesive skin traction should be used instead and that no traction hitch should be allowed to stay on for more than 3 to 4 hours without adjustment. A few patients were admitted with board splints. Many were admitted with plaster slab support for both upper and lower extremity fractures. A few compound fractures of the femur were admitted in plaster hip spica casts. These patients without exception were more comfortable, less tired, and had less fever than those to whom spints were applied by traction and Army splint. Patients with extreme swelling, hemorrhage, or suspected gas infection could not, of course, be so transported. Heavy plaster slabs in most compound fractures (except those of the femur)

probably furnish the best, and the most quickly and easily applied form of splinting for transportation. The wound is easily explored by cutting the bandage for observation or for relief of swelling.

Sulfonamide treatment. Invariably the patients in the Guadalcanal action had wounds treated with sulfanilamide. Patients received from the New Georgia action did not uniformly present this picture. Almost every patient gave a history of having sulfanilamide applied locally at the time of the first dressing and of taking his field "ration" of sulfathiazole when wounded. Thereafter, movement of the wounded to the rear rendered oral therapy haphazard. Less than one-third of the patients probably had adequate oral administration of the drug. It is suggested that every effort be made to use the sulfonamides both locally and orally in therapeutic dosage as it is believed that this is a prime factor in the low incidence of infection.

Débridement. Early débridement plus the use of the sulfonamides provides the best insurance against infection, secondary hemorrhage, gas bacillus infection, and nonunion. The earlier these procedures are instituted the better the insurance. Débridement should be thorough. A massive block dissection of the tract is not as a rule necessary but the skin edges should be excised, the fascia incised and adequately opened, and the muscle planes separated down to the fracture. Foreign material encountered, loose bone fragments, clots, and necrotic tissue should be removed as thoroughly as possible without danger to major nerve or vascular structures. The wound should be packed with vaseline gauze. A cross section of the wound at the completion of the operation should present a conical appearance with the base to the skin surface. In case the operator is inexperienced, or if the patient's condition is such that he will not tolerate a prolonged procedure, enlargement of the wound and vaseline packing to get the "conical" effect should be the goal; thereby evacuation of serum, blood, or pus is promoted. Fixation of the extremity by plaster or splint should follow. Primary reduction of a fracture should not concern the surgeon who is preparing a patient for evacuation to a base hospital. Patients from the Guadalcanal campaign were received without débridement, as a rule within 36 hours. Many were received in as short a time as 12 hours after the wound was inflicted. By "conical" débridement, oral and local sulfathiazole administrations, and casting, temperatures would invariably drop to normal within 4 or 5 days. Only 1 uncontrollable infection developed necessitating amputation at the thigh and this was in a patient who had multiple severe wounds and third degree burns, whose condition precluded satisfactory débridement. Most of the casualties from the New Georgia campaign were received from 2 to 10 days after being wounded. Superficial débridement had been done but the fascia was not incised and foreign bodies and necrotic débris had not been removed. Into the tract usually had been inserted a narrow gauze strip or in some instances a through-and-through Penrose drain, passing between the fractured fragments. To remove this drain necessitated pulling the contaminated end of the drain through the fracture area. The narrow wicks and drains had in some instances sealed in and were acting as plugs to the wound, damming back huge accumulations of blood and pus. A secondary hemorrhage into one of these infected, distended abscesses necessitated amputation in 1 case. Wounds treated with drains and wicks without a wide opening of the tract were invariably infected after 8 to 10 days. Secondary débridement at this time prevented serious trouble in most instances but convalescence was prolonged and early osteomyelitis was more common. *It is our belief that no compound fracture sustained in battle should be closed, unless definitive care can be given in a base hospital within 6 hours after injury.*

Tetanus toxoid, gas bacillus antitoxin. All who did not receive a booster dose of tetanus toxoid were given ½ cubic centimeter of the toxoid on admission. No case of tetanus was met in approximately 2,000 cases of open wounds. Gas bacillus antitoxin was not given prophylactically. No case of gas bacillus infection developed after adequate débridement.

Skeletal fixation by Stader, Roger Anderson, or other apparatus. These types of fixation were not available to us. In many instances

external fixation could have been usefully employed but was not necessary for adequate treatment. All fractures of the femur, except those of the distal end, were suspended, and balanced traction was applied by means of Kirchner wire or Steinmann pin through the femur or upper tibia. Traction was maintained until sufficient callus or fibrous tissue had formed to prevent loss of position in a cast. Hip spicas were applied on a spica box in bed, the traction being maintained until the plaster had set. In fractures of the long bones other than the femur little tendency toward displacement of the fragments was encountered. The usual displacements due to muscle pull were not often seen, the muscles having lost tone due to the impact of high velocity missiles or for other reasons not well understood (further study should be done on this problem). After débridement almost all fractures of long bones other than the femur were reduced by manual traction and manipulation and position maintained by circular plaster casts, replacing heavy anteroposterior plaster slabs after swelling had subsided. Hanging casts were used successfully on most humeral fractures. Sulfathiazole was given orally, 2 grams initially, 1 gram every 4 hours for 3 days, followed by 1 gram 4 times daily until temperature was normal. All wounds were "frosted" with sulfanilamide crystals.

Antishock therapy. Only a few patients on admission were in need of immediate therapy for secondary shock. Plasma, 5 per cent glucose in saline solution, or whole blood was used. For extreme débridements, plasma, whole blood, or glucose in saline was administered as indicated. No patient was lost from primary or secondary shock. All patients gave histories of adequate plasma, sedation, or transfusion for control of primary shock and their condition on admission showed excellent preliminary care and antishock therapy.

Complications. Two cases of secondary hemorrhage were encountered. All occurred in patients from the Guadalcanal action. Four patients who had had amputations, but who had recovered from the gas bacillus infection on admission, were received from the New Georgia action. The incidence of gas bacillus infection was 2.35 per cent in patients with open wounds. Gas bacillus infection occurred in 0.45 per cent of total admissions from the Guadalcanal action. The gas bacillus infections in the New Georgia campaign were not received until after recovery. Five died of this infection, a mortality rate of 14.3 per cent.

No prophylactic gas gangrene antitoxin had been given. Immediate wide and thorough débridement was done in all cases of gas bacillus infection. The wounds were treated with sulfanilamide and were packed open with vaseline gauze. Plaster slab splints were applied. Amputation was performed at once on all patients with thrombosis, severance of the main artery, or gangrene from pressure of the gas. Forty thousand units of gas bacillus antitoxin (Parke-Davis combined gas gangrene antitoxin) were given as soon as the infection was discovered. Twenty thousand units were then given every 6 to 8 hours until the temperature had returned to normal. This required as a rule from 150,000 to 250,000 units per case. Sulfathiazole was given orally, 2 grams for the initial dose, and 1 gram every 4 hours until the temperature had subsided. X-ray therapy was used in 5 cases, in dosages of 75 r twice daily. No gas bacillus infection developed in cases in which a thorough débridement was done. All 35 patients had signs of gas bacillus infection on admission. Thirteen major amputations were performed for this infection. It is our impression that the use of sulfonamides orally and locally in the field and adequate splinting have resulted in this low incidence of gas bacillus infection. The adoption of these measures, with early thorough débridement, should further lessen the incidence of this infection. Thorough débridement combined with open packing and adequate splinting is without question the principal factor in preventing these infections.

Amputations. Up to October 1, 1943, 55 major amputations had been performed, of which 20 were of the upper and 35 of the lower extremities. Of the 55 cases, 25 flap amputations and 30 guillotine amputations were done. Refrigeration anesthesia was employed successfully in 1 case. Flap amputations were used mainly for secondary closures. The responsibility of the surgeon is twofold: first, to remove the gangrenous or infected limb, and,

second, to fashion a stump by means of which a suitable prosthesis can be worn. It is suggested that ice anesthesia, when available, be tried in gas bacillus infection to stop bacterial growth and as anesthetic for amputation.

As to weight bearing, peg leg end-bearing is now rarely employed. Side-bearing limbs which owe their value to support provided by the lateral surface of the stump are now most commonly used. With side-bearing there is no fear of terminal scars, and muscle flaps not biologically adapted to weight-bearing are not used. In tall individuals, double leg amputations, or in primitive people, end-bearing stumps are of more value than side-bearing.

Frequently the surgeon has no choice in selecting the site of amputation because of the nature and location of the wound. Sites of election are arbitrary and are conditioned largely by requirements of limb bearing. Accordingly, a long stump may be just as inadequate as too short a stump. The optimal site in the lower leg is 7 inches below the internal condyle of the tibia. The minimum point is 3 inches below the internal condyle. The Callander amputation is unsatisfactory because of extreme length of bone. Stokes-Gritti amputation is satisfactory if end-bearing is desired. One of the neglected amputations is disarticulation at the knee. The articular surface of the condyle of the femur is biologically fitted for weight-bearing. The classic site of amputation in the thigh is at the junction of the middle and lower third. The shortest practical stump is 3 inches below the greater trochanter. A satisfactory limb can be worn with disarticulation at the hip.

In flap amputations the classical sites of election should be given careful consideration. In war surgery, flap amputations are undesirable. Ordinarily, they should not be done in the presence of massive infections, particularly gas bacillus infections. In selected cases with sulfonamide therapy, however, the risk is not too great. Gangrenous limbs due to vascular ligation following wounds of major vessels can be amputated by the flap method provided infection is not present. In doing flap amputations no tourniquet was used. Equal flaps were cut and the muscles severed by a sharp amputation knife. The bone was then sawed. The larger bleeding vessels were ligated and controlled by hot saline sponges. Muscle flaps were not made, and the bone was not curetted or a periosteal cuff excised. Nerves were not pulled down and injected. The skin flaps were undermined sufficiently to give snug closure. Rubber tissue drains were inserted at the angles of the wound for 48 hours. Before closure the wound was frosted with sulfanilamide crystals.

Guillotine amputation is the procedure of choice in war surgery. It is primarily designed to eliminate destroyed, infected, and nonusable tissue and to provide adequate drainage by remaining open. It must also provide a usable stump and provide for early closure.

The site of amputation should be at the lowest possible level regardless of the utility of the stump and *not* at the site of election.

In performing this operation, generous skin flaps should be provided if possible. These flaps are not closed but are undermined and retracted. Each layer of muscle is retracted as cut, thus making a slightly conical amputation stump.

Because of the large exudation of serum, skin traction is not applied for 24 to 48 hours. Five to 15 pounds of weight are used. The wound is dressed with 5 per cent sulfathiazole ointment.

With traction the skin is gradually pulled down over the stump causing a gradual contraction of the wound. When maximal contraction has occurred, if not entirely healed, secondary plastic closure by removing ⅛ inch to ½ inch of bone end is done.

After stumps were healed provisional plaster pylon prostheses were made. This initiated early shrinking of the stump, trained the patient to balance himself before a permanent prosthesis was obtained and gave him assurance and confidence in ability to get around.

Amputation of the upper extremity is a special problem because of unsatisfactory experience in the last war and in civilian life with the wearing of artificial arms. It is simple to reproduce lost function, that of weight-bearing, by artificial means in leg amputations. Prehension, the function of the hand and arm can only be imitated but cannot be duplicated. For these reasons these patients were operated

upon by the cineplastic method enabling the amputee to utilize the remaining muscles in the stump to operate a prosthesis along natural lines. The double arm amputee must live in a different world. He is helpless and requires assistance even in the minor pursuits of life. In 1 of 2 such cases a cineplastic amputation was performed on one forearm. On the other forcipization was done, the stumps of the radius and ulna being used as fingers.

TABLE I.—SUMMARY OF FRACTURES FROM MAY, 1942, TO OCTOBER, 1943

	Cases		Cases
Total number of patients with compound fractures	615	Radius	53
Multiple fractures	144	Ulna	44
Total number compound fractures	880	Metacarpal	57
Clavicle	16	Phalanges (hand)	67
Ribs	50	Femur	80
Vertebrae	11	Tibia	86
Scapula	26	Fibula	52
Pelvis	25	Patella	10
Humerus	66	Tarsals	50
		Metatarsals	89
		Phalanges (foot)	68
		Carpals	30

HEAD AND SPINAL INJURIES

Patients with head injuries comprised the largest group treated in the neurosurgical service. Many of the Army patients were admitted with the diagnosis of contusion, but were in reality neuropsychiatric problems. Compound fractures of the skull provided the largest part of the operative work. There were 33 patients admitted with a compound fracture of the skull, and 25 of these were operated upon. One of the operative patients died; he had also sustained multiple wounds and an amputation of one leg had been done because of a gas bacillus infection. One patient with a compound basilar fracture died as the result of a severely lacerated cortex. Another patient died from the effects of a shrapnel fragment which penetrated his midbrain. None of the patients with a compound fracture of the skull showed evidence of meningitis while in this hospital. The dura appeared to be intact in 5 of the 25 patients who came to operation. The average interval between the time of injury and operation was 5.68 days, the longest interval being 20 days and the shortest 1.5 days. A few cases of simple fracture were observed. Three patients struck by falling coconuts and rendered unconscious were treated; none showed evidence of skull injury or residual brain damage.

Patients with spinal injuries were handled by both the orthopedic and neurosurgical services. In only 1 gunshot wound of the spine was operation carried out; a laminectomy was performed in the dorsal region and a shrapnel fragment was removed from the substance of the cord. The patient was operated upon 5 days following injury, and during the 2 weeks he was observed following operation no infection was apparent.

Patients with severe spinal cord injuries were treated with oral sulfadiazine, forced fluids, special care to pressure points, change of position every 4 to 6 hours (by rolling them carefully on a sheet), and the use of oral mineral oil, and enemas when needed. Bladder care consisted of the employment of an indwelling catheter, this being clamped off except for drainage every 3 or 4 hours. Although all patients with this bladder regimen showed evidence of cystitis and urethritis, no case of clinical pyelitis was encountered.

Little peripheral nerve surgery was done because of the hesitancy to bury silk in grossly contaminated wounds.

Patients admitted with the diagnosis of concussion, if found on examination to have no abnormal neurological findings, were handled by the neuropsychiatric service.

Patients with intracranial injuries without any associated scalp and skull injuries, were kept in bed from 10 to 21 days, with mild elevation of the head, given adequate fluid intake, and aspirin (with or without codeine) for control of headache. Spinal punctures were not done routinely, but were done when the extent of the cerebral injury was in doubt and when a change in the condition of the patient merited an examination of the spinal fluid.

One patient with a middle meningeal hemorrhage (extradural) was encountered and was operated upon approximately 3 hours after he fell from a truck. The bleeding was controlled by a suture through the dura with ligation of the vessel, and the clot was evacuated and a decompression done. Recovery was uneventful.

Three patients with subdural hematomas were seen; the hematomas were evacuated and

washed out through trepanation or a small decompression. All were drained with a Penrose drain for from 24 to 48 hours.

Treatment of patients with a compound fracture of the skull presented a difficult problem, because of the interval elapsing between the injury and the time of admission at this hospital. Practically all of these patients had been dressed within a short time after being injured and a sulfonamide preparation placed in the wound. Occasionally, a patient had been operated upon prior to admission, but almost all of the patients had dirty, open wounds, 80 per cent of which exhibited exposed cortex, which was often herniating.

Following admission to the ward, the general and local condition was appraised, and if satisfactory, the patient was taken to the x-ray department for stereoscopic studies in the appropriate views. Usually sulfanilamide crystals were applied to the wound at the first dressing, after the scalp was carefully shaved and cleansed with ether. The stockinette type of head dressing was routinely employed. The patient was immediately started on a course of sulfadiazine, receiving 30 grains initially, and 15 grains every 4 hours thereafter. Fluids were forced to at least 3000 cubic centimeters in each 24 hours. Aspirin and codeine were used to control pain; a small dose of morphine occasionally was given. Barbiturates (oral or rectal) were used for control of restlessness, although occasionally it was necessary to use paraldehyde in addition. If the patient was comatose, a nasal catheter was passed, and feeding and medications were thus given. Also, an indwelling catheter was inserted to simplify care of patient, and catheter was clamped off except for drainage every 3 or 4 hours.

Operative procedures in compound skull fracture cases were simplified as much as possible. The scalp was scrubbed with ether and coated with tincture of merthiolate. Procaine, alone or in combination with pentothal sodium, was the anesthetic agent employed. A scalp débridement was first carried out, followed by the removal of contaminated and comminuted bone. The dura was débrided if open. The cortex was débrided if lacerated, and foreign bodies were removed when accessible. The cortical débridements were frequently inadequate because of potential hemorrhage from inaccessible vessels which could not be controlled because of a lack of silver clip equipment and an electrosurgical unit. Softened cortex was then removed by suction. Bleeding was controlled by the use of hot normal saline solution and suction on cotton, and the use of muscle stumps. The scalp, skull, and cortical wounds were irrigated with hot normal saline solution. Sulfanilamide crystals were left in every wound. The dura was frequently left open as it was felt best not to try to slide in a piece of dura that might have already aided in sealing off the spread of infection. All wounds were closed if possible, with one layer of interrupted silk, linen, or cotton (depending on the material available). Sulfadiazine therapy was continued after operation. Some patients were evacuated shortly after operation, whereas the remainder were kept in bed for from 10 to 21 days.

In spite of the fact that operations were carried out in almost every instance after the lapse of the recognized 48 hour period for compound fractures of the skull, no meningitis developed while any patient was under our observation. One patient with a severe frontal bone and lobe injury and some parietal involvement, was admitted with dirty wounds which had broken open after incomplete débridement. A second attempt was made to close the wounds partially and they were draining when he was evacuated. Another patient developed an infection in a postoperative hematoma but this wound was healing when he was evacuated.

As a result of the experience gained at this facility, we would advocate the instillation of sulfanilamide crystals in the wounds of patients with scalp, skull, and spine injuries at the time of the first dressing. Also the routine use of sulfadiazine orally, the early débridement of these wounds (when satisfactory facilities are available), the postoperative use of sulfadiazine, and an adequate fluid intake are all strongly advised.

TREATMENT OF BURNS

At least four cardinal principles must govern the treatment of burns: (1) The prevention and treatment of shock must be the first

and most immediate consideration. This is facilitated by (2) the relief of pain; morphine in adequate dosage is an imperative; an initial dose of ½ grain is not unusual when indicated in severe cases. (3) Further contamination of wounds must be avoided; reasonable cleanliness in the field and an aseptic technique in the hospital is essential. (4) Measures to control the established bacterial contamination are directed toward increasing the resistance of the host by chemotherapy (sulfonamide drugs), by passive immunization (plasma protein and fluid maintenance), and by the maintenance of adequate nutrition.

Sulfonamide therapy. In this hospital, 2 grams of sodium sulfadiazine in 40 cubic centimeters of sterile water is given intravenously soon after admission. Subsequent chemotherapy consists of 4 grams daily, either as 1 gram of sulfadiazine orally every 6 hours, or 2 grams twice daily given intravenously.

It is thought that the administration of sodium bicarbonate in quantities of 10 to 15 grains with each dose of sulfonamide drugs increases solubility of the drug and minimizes complications, such as crystallization in the urinary tract and hematuria. Satisfactory blood level determinations should range from 4 to 10 milligrams per cent.

Complications of sulfonamide therapy may be listed as hematuria, crystalluria, hematuria and crystalluria, fever (otherwise unexplained), fever and rash, and agranulocytosis.

Administration of blood plasma. The initial dosage of plasma is determined on the basis of the surface area of burns. For each 10 per cent of the body surface involved, 500 cubic centimeters should be given within the first 24 hours. It is during this period that most of the fluid loss from the body occurs. Large quantities of fluids intravenously are not urged, except in the case of unconscious patients, when 3000 cubic centimeters may be given daily. Patients able to take water by mouth have been found to co-operate well in the matter of fluid intake. Prompt administration of plasma, up to 12 units, may be required within the first 24 hours. If the patient is in critical shock, the plasma is given rapidly, about 500 cubic centimeters in the first 5 minutes. Subsequent dosage of plasma is based on repeated hematocrit and serum protein determinations.

A simple scale of values for estimating the amount of plasma required, with relation to the hematocrit determination is: hematocrit 60 per cent or over: give 3 units of plasma in the 4 hours preceding the next reading; 55 to 59 per cent: give 2 units of plasma; 50 to 54 per cent: give 1 unit of plasma.

Local treatment of the burn. This topic may be subclassified into (a) first aid measures, and (b) hospital treatment. It should be borne in mind that in extensive burns, local treatment may be instituted simultaneously with the management of shock.

If the skin surface is covered with oil, it should be treated with a detergent. Dreft, drene, and orvus are supplied by the Navy, and are to be used in a 5 per cent solution. Sterile lard or mineral oil may be used when other agents are not available. Blisters should not be opened, and destroyed skin should not be removed. The area is not to be washed unless there has been gross dirt or fecal contamination, in which case cleansing and removal of skin tags should be left to the discretion of the medical officer. White soap and water are to be used; green soap is not recommended. A booster dose of ½ cubic centimeter tetanus toxoid should be administered routinely in all cases. The dressing in the first aid treatment of burns should be oily and nonadherent. Petrolatum or vaseline gauze dressing is excellent for this purpose. A moderately thick layer of gauze or cellotex is placed over this primary dressing, and the whole is covered with a snug muslin bandage. Splinting of extremities is recommended.

When the patient is received primarily in the hospital, the local treatment of the lesion is carried out in the following manner: oily surfaces are cleansed with dreft, drene or orvus in 5 per cent solution, as mentioned in the preceding paragraph. Under aseptic precautions, including the use of sterile instruments, careful débridement of all blisters and loose shreds of skin and tissue is done. Deeper tissue which may appear to be damaged should not be débrided at once; this may be done secondarily in a few days, if necessary, after demarcation between healthy and necrotic

areas has become apparent. After cleansing, the various methods of treatment are available. It is recommended, however, that all burns be treated as open wounds. Fine mesh sterile gauze impregnated with petrolatum or vaseline is used as a primary layer in the dressing. A smooth, thick layer of sterile gauze is applied over this, and held in place by a smooth, evenly applied bandage. Firm pressure is important, as it minimizes the loss of serum. When possible, splinting of extremities is advised. If no complications ensue, dressings are left in place for 10 to 14 days, after which most first and second degree burns will have healed. Unless fever, odor from the dressings, or excessive purulent discharge indicate infection and contamination, even original first aid dressings may be left in place for the 10 to 14 day period. When first aid dressings are removed in the hospital, it is advised that the medical officer and all assistants be masked, and that the burned area be treated always as an open wound. Third degree burns should be prepared for grafting by excision of all dead tissue. If suppuration is present, further preparation is, of course, necessary. However, wherever full thickness skin loss has occurred, skin grafting should be carried out at the first possible moment.

Management of infected cases. Immersion baths in warm saline solution are an invaluable aid in cleansing discharging surfaces of secretions and débris. The patient is immersed in a tub, when practicable, twice daily for an hour or more, depending upon his condition. In those necessarily confined to bed, hypertonic saline soaks are of value; wet saline dressings, moistened at frequent intervals, are applied over raw, infected surfaces after the application of sulfanilamide dusting powder to control spreading of the local infection.

In patients manifesting secondary anemia, transfusions of citrated blood in 500 cubic centimeter quantities, given as frequently as necessary to bring the blood count to a satisfactory level, are used. Heavy doses of vitamin C and thiamin chloride to supplement a high vitamin, high protein diet are given.

Other methods of treatment. These include spraying with gentian violet (2 per cent aqueous solution), spraying with triple dye, 1 per cent sulfanilamide in mineral oil, 1 per cent sulfathiazole ointment (this has been found to be as effective as stronger concentrations) and boric acid ointment dressings (not recommended in the tropics because of chemical changes in the boric acid).

Tannic acid, in aqueous solution, in jelly, or in a spray combined with silver nitrate, is no longer used at this activity. However, inasmuch as a tannic acid jelly was the only agent available to us in the treatment of 91 cases from May, 1942, to May, 1943, its application was our principal method in the management of these burns. Briefly, our cases were divided into two types: clean cases, received within 24 hours from the injury, and infected cases, in which more than 24 to 48 hours had elapsed since the burn. Clean cases were débrided in the operating room, under anesthesia when necessary. The débrided surfaces were sprayed with sulfathiazole powder, by means of an ordinary nasal atomizer, then covered with a thin layer of tannafax jelly, applied with an ordinary sterile wooden tongue blade. The patient was then placed under a heat cradle; formation of a thin eschar occurred quickly. Infected burns were handled as open wounds, saline immersion baths were used and the wound was covered with sulfathiazole ointment. In both the clean and infected cases, healing of first and second degree burns occurred with satisfactory rapidity; third degree burns were necessarily individualized, secondary débridement being done often when demarcation of necrotic tissue was manifest.

Since results were so uniformly good with this method, it was not felt necessary to depart from this routine. The thin, flexible eschar, or so called tannic "crust," provided many advantages in the handling of these patients; among them should be mentioned early relief of pain by sealing over exposed nerve endings, elimination of the necessity for drainage, prevention of serum loss, and the evacuation of patients, when necessary, with greater facility. We are still of the opinion, based on our own experience, that the sulfathiazole powder spray under a thin, flexible tannic acid eschar deserves its proper place in the armamentarium of burn therapy.

WOUND DISRUPTION

A Study of 55 Cases at the Cincinnati General Hospital

SABRO TASHIRO, M.D., Cincinnati, Ohio

IN recent years numerous studies of abdominal wound disruptions have been made. Jenkins in 1937 summarized the literature upon the subject, collecting a total of 1,683 cases, of which 389 were reported by American workers. The 15 cases collected by Hinton were not included. Singleton and Blocker and Hartzell and Winfield (16) in 1939 published additional data supplementing Jenkins' statistics which, with other series reported since that time (3, 9, 18, 30, 40), raise the total of abdominal wound disruptions reported in this country to approximately 720 cases.

A review of the operating room files of the Cincinnati General Hospital for the 10 years beginning January, 1933, shows that there were 55 eviscerations of laparotomy wounds during that period. It is realized that this figure may not represent all cases of evisceration which occurred during this period, since some patients who suffered this complication may not have been treated surgically, while others may have undergone secondary suture on the wards.

DEFINITION

The term "disruption" as employed in this paper will refer to those cases in which any portion of the peritoneal cavity or its contents presented in the wound. Among the words used as synonyms for this condition by various authors are: dehiscence, rupture, eventration, evisceration, avulsion, and separation. During the 10 years between January 1, 1933, and January 1, 1943, 8,346 laparotomies and 2,150 elective herniorrhaphies were performed in this clinic. The distinction between laparotomies and herniorrhaphies is made because (1) no eviscerations occurred in the latter group, and (2) certain investigators (7, 26) include herniorrhaphies in calculating the indence of wound disruption. If the incidence of wound disruption is based on the total of 8,346 laparotomies, the percentage is 0.65 per cent, whereas should herniorrhaphies be included the percentage would be 0.52 per cent. A comparison of our statistics with those of other clinics is presented in Table I.

TABLE I.—COMPARISON OF STATISTICS

1933–1943	Total cases	Number of disruptions	Per cent
Cincinnati General Hospital...	8346	55	0.65
1934 Colp.....	2750	26	0.54
1936 Koster and Kasman..	7892	17	0.22
1936 Glasser†.....	3234	8	0.24
1939 Singleton and Blocker*	9000	61	0.67
1939 Hartzell and Winfield†	6532	33	0.5
1941 Hesseltine and Bohlender†.....	3179	15	0.47

*Elective herniorrhaphies not included in calculations.
†It is not definitely stated that herniorrhaphies were included.

The distribution of our cases over individual years was as follows: in 1933, 7 disruptions; in 1934, 4; in 1935, 4; in 1936, 7; in 1937, 3; in 1938, 2; in 1939, 5; in 1940, 9; in 1941, 2; in 1942, 12.

These figures might suggest the influence of certain variables as the following: changes in technique, suture material, different surgeons, and preoperative and postoperative management. It is thought by some, however, that variations from year to year could be within the realms of chance. Thus Maes and his coworkers collected 44 cases of wound disruption over a 10 year period, the distribution of which, as compared with our cases, is shown in Table II.

Maes stressed that in the 13 cases of disruption occurring in 1933 operation was performed by 13 different surgeons for 13 varieties of diseases. Milbert also emphasized the rôle of chance: stating that 6 of the 30 cases which he collected occurred during a 2 week period. Bettman and Lichtenstein and Schmitz and Beaton have also commented on the sporadic occurrence of wound disruptions. In the 2 cases which occurred at this hospital in 1938

From the Department of Surgery, College of Medicine of the University of Cincinnati, and the Cincinnati General Hospital.

TABLE II.—COMPARISON OF CASES OF WOUND DISRUPTION

Maes, Boyce, and McFetridge		Cincinnati General Hospital	
Year	No. of disruptions	Year	No. of disruptions
1924	5	1933	7
1925	0	1934	4
1926	2	1935	4
1927	7	1936	7
1928	1	1937	3
1929	1	1938	2
1930	0	1939	5
1931	0	1940	9
1932	5	1941	2
1933	13	1942	12

operation was not performed by members of this visiting or resident surgical staff.

The distribution of the 55 cases by services was as follows: general surgery, 43; gynecology, 8; obstetrics, 1; operated on outside, 1; Police-Fire Department, 2.

The age distribution is listed in Table III.

The youngest patient in this group was 36 hours of age. No younger case could be found in the literature. The other patient in this first group was 6 weeks of age. The oldest patient was 72 years of age. The average age for the entire group was 48.3 years. It is noted that 47 cases occur in the decades between 30 and 70. The majority of workers, including Colp, Singleton and Blocker, Kross and Glasser, place the most common ages for disruption between 30 and 50. In the series collected by Maes and his co-workers, 63.6 per cent of the disruptions occurred in patients between 10 and 40 years of age. The distribution in our group corresponds to the observations of Meleney and Howes, Milbert, and Koster and Kasman (26).

Most investigators agree that age is not a factor and that the seeming preponderance of disruptions in the years between 30 and 50 years is explained by the fact that the major portion of a given hospital population falls within these limits.

TABLE III.—AGE DISTRIBUTION, OUR SERIES

Age	Number of disruptions	Per cent
0–9	2	3.6
10–19	0	0.0
20–29	3	5.4
30–39	11	20.0
40–49	11	20.0
50–59	12	21.8
60–69	13	23.6
70–79	3	5.4

Of the 55 cases in our group, 40 were males and 15 were females. It is generally believed that the sex of a patient does not influence the incidence of wound disruption. A few authors as Milbert and Colp however, believe that males are more subject to wound disruption than females because of (1) abdominal breathing; (2) greater physical activity; (3) less elasticity of abdominal wall than females; (4) greater use of alcohol and nicotine. No opinion that women are more prone to wound disruption can be found in the literature.

Of the 53 cases in our series, 14 or 25.4 per cent were in negroes. This figure is of little significance since it is not known what percentage of patients submitting to surgery were of that race.

Boland studied the incidence of evisceration in negroes. Over a 10 year period during which 4,337 laparotomies were performed, there were 12 eviscerations, or 0.28 per cent. The author concluded that the condition occurred less frequently in negroes than in white patients. It was suggested by Boland that the predisposition of the negro to keloid formation may be a factor. Although Maes and his co-workers also found that dehiscence occurred less frequently among negroes, in their series, these authors believed that race was not a factor. Furthermore, Baldwin, Kennedy, Koster and Kasman (26), and others have published reports in which the studies were not confined to negroes, and in which the incidence of wound disruption was less than that reported by Boland.

Of the 55 cases in our study, 33 or 60 per cent occurred in winter or spring. Sokolov, reviewing cases occurring in northern Europe, stated that eviscerations were more common in winter and spring. This finding was attributed by the author to the scarcity of fresh vegetables in the diet during these months with resultant tissue deficiencies.

Maes and his co-workers and Colp thought that seasons had no influence, the former stating that the dietary problems of northern Europe cannot be compared to those of the United States.

Hartzell and Winfield (17) reported 20 disruptions from November through April, and 13 from May through October. The difference

was ascribed by these authors to a greater incidence of upper respiratory infections during the winter months.

PRIMARY DISEASE

Debility. Many authors have discussed the influence of certain diseases and constitutional conditions upon the incidence of evisceration. It is felt by some that the healing power of tissue is impaired in such conditions as diabetes mellitus, pernicious anemia, cholecystic disease, peptic ulcer, carcinoma, tuberculosis, general debility, and syphilis.

Hartzell, Winfield, and Irvin (17) have presented convincing data in support of certain phases of this theory. The data will be considered later.

Briefly reviewing our series: As regards concomitant disease there were 12 cases of carcinoma, 2 of tuberculosis, 1 of pernicious anemia, 12 of peptic ulcer, 8 of cholecystic disease, and 10 of systemic or central nervous system syphilis and no cases with diabetes mellitus, a total of 42, or 79.2 per cent of the group.

Colp believes that generalized debility resulting from either the primary disease or associated conditions is the major cause of postoperative wound disruption. Sokolov in his exhaustive work directed attention to the fact that many of the 723 cases which he collected occurred during the years of starvation or dietary deficiency following the last World War.

Heyd and Starr and Mason independently expressed the belief that debilitating influences are the primary cause of evisceration in a restricted group of cases.

At the other extreme are the proponents of the belief that primary disease or associated debilitating conditions play no part in evisceration. Glasser and Cave stress that prompt healing occurs in many patients suffering with wasting diseases and emphasize the usual uncomplicated rapid healing which follows secondary closures of wound disruptions.

Koster and Kasman (26) also dismiss primary disease or concurrent debilitating conditions as not contributory.

Habitus. Of our series, 10 patients (18.1 per cent) were described as obese; 16 (29.0 per cent) as poorly developed and poorly nourished; 20 were well developed and well nourished, while the habitus of 9 was not described. Milbert cited the theory of Livingston in regard to the relation of habitus to intra-abdominal pressure. It was the belief of the latter that the intra-abdominal pressure of obese individuals was greater than normal because of the presence of increased mesenteric intraperitoneal and abdominal wall adipose tissue. The author believed that in cachectic individuals, wasting of the tissues of the abdominal wall reduced the ability of that structure to withstand and absorb shock. Hume, also cited by Milbert, observed in normal individuals an increase in the intra-abdominal pressure of from 100 to 150 millimeters of mercury with descent of the diaphragm and contraction of the abdominal muscles. Should one consider the change in intra-abdominal pressure resulting from postoperative complications as distention, cough, singultus and emesis, the theory of Livingston cannot be disregarded.

Of the 55 cases in our series 54 operations were performed by 26 surgeons. The operator in the remaining case was not known. Two surgeons each had 5 cases of wound disruption.

PRIMARY OPERATIONS

The primary operations are presented in Table IV.

TABLE IV.—PRIMARY OPERATIONS

	No. of cases	Per cent
Biliary tract	8	14.5
Gastric resection	7	12.7
Closure ruptured peptic ulcer	5	9.0
Supravaginal hysterectomy	5	9.0
Salpingoophorectomy	4	7.2
Gastroenterostomy	2	3.6
Gastrostomy	2	3.6
Exploratory laparotomy—including	12	21.8
Volvulus		
Tuberculous peritonitis		
Retroperitoneal hematoma		
Intestinal obstruction (2)		
Carcinoma of large bowel (2)		
Carcinoma of stomach		
Stab wound of abdomen		
Miscellaneous—including	10	18.1
Splenectomy		
Instrumental perforation sigmoid		
Ramstedtt pyloroplasty		
1st stage Whipple (2)		
Transverse colostomy		

Anesthesia. The types of anesthesia employed at the primary operation were distributed in the following manner: spinal 5 (9.0 per cent), local 9 (16.3 per cent), and general 39 (70.9 per cent). Of the latter, 2 were begun under spinal and 1 under local anesthesia. The type of anesthesia used in 1 patient operated upon at another hospital is not known.

It is difficult to demonstrate a definite relationship between wound disruption and the type of anesthesia used at the primary operation.

Koster and Kasman (26) reported 3,234 patients who were operated upon under spinal anesthesia in 0.22 per cent of whom evisceration occurred. It is not known whether femoral and inguinal hernias were included in this series. The authors stated that spinal anesthesia afforded maximum relaxation and ease of exposure and closure.

Milbert reported 1,500 patients (excluding inguinal and femoral hernias) operated upon under inhalation anesthesia in whom there was evisceration in 1.28 per cent.

Colp does not believe anesthesia to be a factor. Glasser and Eliason and McLaughlin noted that the often incontrollable behavior of patients attending a premature cessation of anesthesia may result in undue strain.

Maes, Boyce, and McFetridge wrote that faulty anesthesia could be considered as contributory to only 1 of their 44 cases of wound disruption.

Incisions. The operative incisions employed in the cases under consideration were distributed in the manner shown in Table V.

TABLE V.—OPERATIVE INCISIONS

Incision	Disruptions	Per cent total
High right rectus	22	40.0
High left rectus	7	12.7
Low left rectus	3	5.4
Low right rectus	1	1.8
Midline umbilicus to pubis	9	16.3
Left rectus (level not specified)	5	9.0
Right rectus (level not specified)	1	1.8
Transverse	4	7.2
No record	3	5.4

The correlation of operative incisions and eviscerations is discussed by many authors.

Most investigators are convinced that upper abdominal incisions disrupt with greater frequency. Sigalas, Freeman, and Starr and Mason dispute this point. Kross does not believe that the site or type of incision is a factor.

Vertical upper rectus incisions are thought by many to be more likely to disrupt because they are not anatomical. Such incisions transect the normally transverse fibers of the posterior rectus sheath, the predominantly transverse elastic fibers of the skin and the vascular and nerve supply in this region. Furthermore, because of the costal attachments of the anterior abdominal wall, a marked lateral stress is induced by common postoperative strains as cough, emesis, distention, and singultus.

Cave suggested that rectus splitting incisions result in the atrophy of a strip of muscle. Lahey condemns the midline incision as predisposing to accumulation of serum between the bellies of the recti.

Colp, however, has closed 231 upper midline incisions (the majority were cases of gastric disease) with through-and-through black silk sutures only, without dehiscence.

The so called anatomical transverse incision is favored by Whipple and Elliot. Singleton and Blocker describe a modified Sloan incision and report 292 vertical upper abdominal incisions with 9 eviscerations against 470 transverse upper abdominal incisions with no eviscerations. Meleney and Howes, Grace, and Koster and Kasman (26) have reported eviscerations through transverse incisions. It will be noted that 4 of the disruptions in our series occurred through transverse incisions. Six of the 44 eviscerations reported by Maes, Boyce, and McFetridge occurred through McBurney incisions. The latter also reported evisceration occurring after repair of a direct inguinal hernia.

Drains. Of the series under survey only 9 (16.3 per cent) patients were drained, 7 of these through a stab wound lateral to the operative incisions, and only 2 through the operative incisions. The fact that a wound has been drained suggests often that there had been more than the normal amount of exudate, or operative manipulation and implies a stormier postoperative course.

Singleton and Blocker reported the incidence of evisceration in drained and undrained wounds as 1.99 and 0.59 per cent, respectively, while Colp making a similar comparison, submitted 1.22 and 0.84 per cent.

Cave reports 21 cases of postoperative hernia following drained McBurney incisions and none following 282 undrained wounds of the same type. Boland, Maes, and his co-workers, Hartzell and his co-workers (16) have suggested that drains may establish an avenue of protrusion for omentum or bowel. Glasser, however, claims that there is but a single case to be found in the literature in which evisceration occurred through a drainage tract. Meleney and Howes believe that drains are too often used, and observed that "in many cases of established infection of the peritoneal cavity drains do very little good." Jenkins states that continuous sutures should not be placed contiguous to drains because of the possible erosion and severance of the former.

Primary closure. As can be expected, the methods of closure varied considerably. A rough tabulation of the type of closures employed is given in Table VI.

TABLE VI.—TYPES OF CLOSURE

Type of closure	No. of cases	Per cent
All catgut with exception of skin	24	43.6
Silver wire through-and-through	6	10.9
All silk	10	18.1
Combination of silk and catgut	10	18.1
No description available	5	9.0

In the majority of cases, regardless of the type of suture used, the abdomen was closed in layers with interrupted figure-of-eight sutures. In reviewing the cases, one concludes that no method of closure is prophylaxis against evisceration.

The method of closure advocated by most authors is the use of plain or chromic catgut for peritoneum and fascia, nonabsorbable sutures for the skin and stay sutures of silk, dermal, silkworm gut or wire. The catgut used for the closure of the rectus sheath is generally of the No. 2 chromic variety used as a continuous or interrupted suture. Meleney and Howes believe that No. 0 chromic catgut is of adequate strength, stating that the holding power of the sutured tissues, including the rectus fascia, does not exceed the tensile strength of No. 0 chromic catgut. Whipple prefers the use of fine silk in clean wounds.

Hinton and Kennedy use through-and-through sutures of silkworm gut. Hinton believes that some patients are allergic to catgut while Kennedy believes that all buried sutures act as foreign bodies and ligatures.

Kennedy and a senior associate have used through-and-through silkworm gut sutures for 56 years without a single disruption. His only departure is the use of fascial mattress sutures of silk in cases of hernia.

Hinton, however, cites 2 cases of disruption which occurred with this type of closure. Baldwin reports 16,485 cases without a single disruption in which the closure was as follows: (1) continuous No. 2 chromic catgut in peritoneum; (2) reversed through the rectus muscle; (3) reversed and locked in the fascia; (4) three silkworm gut stay sutures; (5) continuous catgut No. 2 sutures for the skin.

Postoperative strains. It is the opinion of most investigators that postoperative strains are either a primary or secondary cause of evisceration. After a review of our records the incidence of some of the more commonly implicated postoperative strains were tabulated (Table VII).

TABLE VII.—POSTOPERATIVE STRAINS

Contributory causes	No. of cases	Per cent of total
Cough	38	69.0
Distention	24	43.6
Emesis	24	43.6
Wangensteen suction / Gastric lavage	18	32.7
Abdominal cramps	7	12.7
Mental confusion	14	25.4
Singultus	3	5.4
Bronchial asthma (severe)	1	1.8
Out of bed	5	9.0
Tried to get out of bed	2	3.6
Bladder distention	1	1.8

Glasser believed unusual postoperative strains to be the sole cause of evisceration. Whether primarily or secondarily a factor, their rôle in evisceration is seemingly important since the force of sudden intra-abdominal strains apparently can cause silk to tear through fascia and also result in rupture.

A point of some interest is the fact that 11 patients who eviscerated were encouraged to

cough. These 11 cases occurred during the past 3 years. No record of this method of prophylaxis against atelectasis is found in the nursing notes prior to 1940, although it was undoubtedly used.

Anemia and plasma protein, vitamins. In recent years much attention has been directed toward the significance of anemia, hypoprotinemia, and vitamin deficiency in wound disruption. These factors will be considered in that sequence.

Since the Tallqvist method was used in many hemoglobin determinations and since hematocrit determinations were performed on only 8 patients, the findings of anemia are not too accurate. Should one consider 4 and 3.25 million cells per cubic millimeter as expressing significantly subnormal red cell counts in the male and female respectively, and 12 and 10 grams per 100 cubic centimeter for similar hemoglobin levels, 24 (43.6 per cent) of the 55 patients were anemic at some time during their hospitalization. The red blood count and hemoglobin determinations of 21 (38.1 per cent) patients were normal throughout their hospital stay. A total of 10 (18.1 per cent) patients apparently had no red cell counts or hemoglobin determinations during their course in the hospital. Of the 24 patients considered anemic during some phase of their hospitalization 11 did not receive transfusions of blood or plasma.

Anemia, plasma protein, vitamin C. Only 4 patients had plasma protein and hematocrit determinations before operation although 36 of 55 cases were elective. The findings in the 4 cases were normal.

Four patients had plasma protein and hematocrit determinations after the primary operation. In all of these the plasma protein determination was below 6.25 while the hematocrit was normal.

Seven patients had plasma protein and hematocrit determinations following disruption. In one group of 7 cases, 4 patients exhibited normal plasma proteins with hematocrit readings below 35 in 3; while the remaining 3 were characterized by plasma protein levels below 6.25 and normal hematocrit readings.

In our series of cases 2 patients received vitamin C before the first operation, 6 received the preparation before the second operation, and 12 after secondary closure.

Thompson, Ravdin, and Ingalls performed investigations upon dogs and demonstrated that in hypoproteinemic states there was acceleration in the absorption and decrease in tensile strength of catgut. These authors noted that experimental wounds in hypoproteinemic animals showed grossly: edema, a pallor, and an unhealthy appearance with a minimum of bleeding, and finally the presence of serous fluid. Microscopically there was (1) a minimum of fibroblastic proliferation; (2) an increase of intercellular fluid. Of 11 animals with hypoproteinemia and operative incisions there was disruption or failure to heal in 8 cases. The authors then made abdominal incisions in hypoproteinemic animals and administered lyophile serum after operation. Healing was grossly normal while microscopic examination showed only intercellular edema. The authors submitted a corollary in that lesions of the stomach, duodenum, and biliary tract were often characterized by hypoproteinemia.

Hartzell, Winfield and Irvin (17) studied 20 cases of abdominal wound disruption occurring in a single year. In all cases the serum protein was below their normal of 6.5 grams per 100 cubic centimeters. The plasma vitamin C determination in all but 1 of the 20 cases were below the author's normal of 0.7 to 2.0 milligrams of ascorbic acids per 100 cubic centimeters of blood plasma.

Numerous investigations on animals and at least 1 man (8, 32) indicate that vitamin C is intimately involved in collagen formation.

Ingalls and Warren stressed that patients with peptic ulcer were prone to vitamin C deficiency because ulcer diets exclude many foods containing vitamin C, while the alkalies which many were taking tended to destroy the vitamin.

The dosage of vitamin C is a matter of much dispute. Wolfer and Hoebel (52) advise a dosage of 1000 milligrams a day for 9 or 10 days, followed by a dosage of 300 to 500 milligrams a day until the wound has healed. Some workers advise lower dosages. Like the majority of investigators Wolfer emphasizes the importance of determination of vitamin C

excretion in the urine, since this is the only reliable easily available index of the vitamin C requirements of the body.

ETIOLOGY

We have mentioned several of the theories presented as to the etiology of evisceration.

Hartzell (16, 17) and his associates stress the rôle of protein and vitamin C deficiency. The work of Ingalls and his colleagues with hypoproteinemic dogs has been mentioned. Koster and his co-workers (27, 28) dispute the influence of subnormal plasma protein.

Wolfer and Hoebel (51, 52) ascribe a major rôle to vitamin C starvation.

Glasser, Milbert, and Murphy believe the complication to be due to strains and increased intra-abdominal pressure.

Lahey believes that seratomas and hematomas are the cause of disruption. There is very little evidence to support this theory.

The theory of Freeman has received accord from several authors (5, 6, 46). It was Freeman's concept that imperfect and incomplete closure of the peritoneum resulted in the incarceration of omentum or bowel. With resultant edema and exudate the incarcerated tissues acted as a progressively enlarging wedge, which enabled additional intra-abdominal contents to escape.

Kross and Sims attempted to demonstrate the validity of Freeman's theory in experimental animals. The former succeeded in producing evisceration in 37.5 per cent of 16 rabbits by leaving a portion of the abdominal incision open or by loose sutures of the latter.

Sims stated that injection of a lymph-like substance found in the experimental wounds which included incarcerated omentum provided digestion of the abdominal wall tissues when injected into other animals.

Kraisel, Hinton, and Babcock independently express the belief that some patients are allergic to catgut, but their theories have received considerable criticism.

Meleney and Howes approach the subject from a standpoint of a lag in the normal process of healing, and tissue and suture strength.

Whipple and Elliot stress a combination of some of the conditions given and mention infection as a contributory cause.

Norris believes that improper closure is the chief cause.

Ducuing described thrombophlebitis in 4 of 5 cases.

Weber postulated a decreased *p*H of tissues causing dissolution of suture material.

No conclusive evidence has been submitted by any author, however.

PATHOLOGY

Nothing of very characteristic nature is known about the morbid anatomy of evisceration. The lack of definite data in regard to the pathological findings is perhaps a proof of the meager knowledge of the condition.

The gross appearance of the disrupted wounds in our series was not described in 4 instances. In 5 cases it was stated that the wounds were grossly infected. In 10 cases definite mention was made of the absence of infection. In 34 cases no definite statement was made. The remaining operative notes are lacking.

In 5 cases closed throughout with black silk it is stated that the sutures had torn through the tissue, although the knots had not been loosened or untied. In 1 case closed with catgut and silk, the figure-of-eight fascial silk sutures had broken.

In 6 cases closed with through-and-through silver wires, the wires broke in 3, in 2 a loop of bowel had extruded between unbroken silver wires, and in the last gross infection with breakdown of the wound necessitated secondary closure.

In 7 cases in which catgut was used the sutures were described as in shreds, disintegrated, or rapidly absorbed.

As has been noted in the literature there was seldom active bleeding from the wound edges. In fact no mention of hemorrhage is found in any of our operative notes. It has been observed by various investigators that the wound edges were "brittle and soft" (3), "dirty and glassy" (26) or like "chronic granulation tissue" (50). The notable absence of bleeding has been used as evidence of some (26, 50) that disruptions occur long before they are recognized and that active bleeding had ceased when the complication has been discovered.

EVISCERATED STRUCTURES

The most common of the intra-abdominal contents presenting in the disrupted wound was the omentum which was noted in 20 (36.3 per cent) cases. Small bowel was noted in 10 cases (18.1 per cent). In 15 additional (27.2 per cent) cases the operative note includes mention of bowel but does not specify whether it was small or large bowel. Among other viscera mentioned as presenting in the disrupted wounds were the transverse colon, stomach, bladder, and liver. The only account of the histological picture of the tissues forming the edges of an eviscerated wound in the human being is given by Glasser who stated that "section revealed an infiltration with lymphocytes and leucocytes, especially in the subcutaneous fat tissue. The fat tissue showed a greatly increased number of fat nucleii with diminution of the fat forming large intercellular septa."

The signs and symptoms of wound disruption are meager. In many cases the temperature and pulse may show no elevation. Pain is not thought to be a common symptom. Glasser observes that evisceration may be accompanied by signs of shock. Several authors stress the presence of signs of intestinal obstruction with disruption due to incarceration of a loop of bowel in the wound. The patient may volunteer the information that there was a sensation of "something giving way." There may be fullness, bogginess, or crepitus beneath the often intact skin. Lahey recommends probing the incision in such cases.

The most common finding in eviscerated wounds is the presence of a serosanguinous discharge which may occur several days after disruption.

In 24 (43.6 per cent) of our series a serous or serosanguineous discharge was noted. Seven (13.4 per cent) cases were characterized by exudate of various types which included bile-tinged and purulent drainage. In 24 cases (46.1 per cent) no descriptions of exudate could be found.

The average date of disruption was 7.5 days after the primary operation. This is in accord with the statistics found in the literature in which the most common date of disruption is placed between the 5th and 9th days. The earliest disruption occurred 16 hours after the primary closure, the latest on the 17th and 19th postoperative days. The incidence of disruption in relation to the postoperative day is given in Table VIII.

TABLE VIII.—INCIDENCE OF DISRUPTION

Day of disruption	No. cases	Tota
1	2	3.6
3	1	1.8
4	1	1.8
5	3	5.4
6	9	16.3
7	13	23.6
8	12	21.8
9	5	9.0
10	3	5.4
11	1	1.8
12	3	5.4
17	1	1.8
19	1	1.8

It was the opinion of several authors (15, 50, 13) that the high incidence of wound disruption between the 5th and 9th days is more apparent than real. It was pointed out that skin sutures are generally removed during this period, and that a common early finding in evisceration is the disruption of all layers subjacent to the skin, suggesting that the process had begun some time previously.

SECONDARY CLOSURES

In a preceding paragraph it was stated that there may have been cases of wound disruption in our clinic which may not have been treated surgically. This is improbable, although statistics are not available. To the knowledge of the author there were no cases in which patients were treated nonsurgically or by delayed secondary closure.

The treatment of evisceration in this clinic has always been immediate secondary closure with through-and-through silver wire or steel wire sutures. This same procedure was outlined by Reid, Zinninger, and Merrell for primary closure of potentially infected wounds. Twenty-six surgeons performed the secondary closures.

In 33 cases, 60 per cent, local anesthesia was employed. In 21 cases, 38.1 per cent, general anesthesia was used; in 1 of these 21 cases to supplement local anesthesia. Intravenous anesthesia was used in 1 case, 1.8 per cent.

Method. The method of secondary closure in 48 cases, 87.4 per cent, consisted of through-

and-through steel or silver wires with cutaneous sutures of fine black silk. Variations found within this group include 2 patients in whom drainage was carried out and 4 patients in whom the closure was re-enforced by peritoneal or fascial sutures of catgut or silkworm gut.

In 1 case closure was with through-and-through braided silk, and in another with silkworm gut through-and-through sutures. In the latter drainage was carried out.

In 1 case a loop of bowel had extruded between the silver wires. After the wires were loosened the bowel was reduced and the wires were again tightened.

The operative notes of 4 secondary closures were not available.

TREATMENT

There is a general agreement on the broader aspects of the treatment of evisceration. The majority agree that immediate secondary closure is desirable in those cases in which the procedure will be tolerated. Those patients whose condition is critical are treated with adhesive tape strapping with or without packing.

All types of anesthesia have been recommended, but the possibility of further evisceration during a difficult induction of general anesthesia is to be considered (18). Through-and-through sutures of silkworm gut (13), silver wire (39), No. 2 chromic catgut, braided silk and dermal sutures have been used in various clinics. Other workers have used layer closures (13) or a layer closure supplemented by through-and-through sutures (3). Some men (13, 46) have advocated enterostomies prior to secondary closure. Pool and Starr and Mason advocated needle aspiration of dilated bowel prior to closure.

Colp, Shipley, Meleney and Howes describe fundamentally the same method of modified secondary closure. The wounds are packed with gauze over which through-and-through sutures are placed. As the subsequent steps the sutures are drawn up as the packing is removed, until several days later the granulating surfaces are approximated. In a somewhat similar fashion, Horner placed a rubber dam over the eviscerated bowel and placed fascial sutures over this tampon. The use of drains is advocated by Bellin and Glasser.

Adhesive tape approximation, simple packing, or a combination of the two is employed in patients (14) who are in critical condition and by some for infected wounds. The mortality of patients treated by immediate secondary closure is much less than for those treated with delayed closure. This is explained in part by the generally more critical condition of patients treated by the latter method.

MORTALITY, FOLLOW-UP

Only 1 patient in our group suffered recurrence of evisceration. In this case disruption occurred 7 days after through-and-through silver wire secondary closure. Bowel had extruded between the intact silver wires. The latter were removed and tertiary closure by the same method was performed. The patient was dismissed subsequently in good condition. At least 6 cases (26, 16, 21, 33) of recurrence are found in the literature; one of the patients died after evisceration recurred following unsuccessful secondary and tertiary through-and-through closures (23).

The extremely low incidence of recurrence after secondary sutures has been stressed by Cave, Kross, Glasser, Bellin, and Starr and Mason. No satisfactory explanation has been given for this phenomenon. One possibility is suggested by the work of Meleney and Howes who demonstrated that healing is divided into two phases, an exudative and a reparative phase. The initial stage is rapid, but decreases in rapidity at the end of 7 to 10 days. Were evisceration to occur in patients with delayed or impaired healing at the period of maximum weakness, it is conceivable that secondary sutures in the average case might be performed at the approximate onset of the accelerated stage of healing.

Boland describes a remarkable case of healing after secondary suture. Nine days after the primary operation the surgeon removed the sutures. The surgeon then went out of town. Evisceration occurred and the wound was secondarily closed with through-and-through sutures by the surgeon's associates. On the following day the surgeon visited the

patient and believing that he had forgotten to remove the sutures, proceeded to do so again. The patient recovered without incident.

There were 22 deaths in our series, a mortality of 40.0 per cent which compares reasonably with the statistics from other clinics. Meleney and Howes, 44 per cent; Colp, 28 per cent; Grace, 39 per cent; White, 55 per cent; Maes, Boyce and McFetridge, 30 per cent.

The most common causes of death were peritonitis and pneumonia. Among other causes of death were: the hepatorenal syndrome subacute bacterial endocarditis, and uremia. One patient returned to the hospital 1 month after secondary closure, suffering with intestinal obstruction, and died following an operation for that condition. Of the 32 patients, 58.1 per cent, that recovered no follow-up is available in 12 instances. Nine, or 43 per cent, of the 21 remaining patients developed hernias or defects in the operative scars. Three, or 14 per cent of the 21 patients who were followed were readmitted with intestinal obstruction from 2 to 3 years following the secondary closure.

CONCLUSIONS

1. Fifty-five cases of laparotomy wound disruptions are reviewed.

2. It is believed that wound disruption results from a combination of factors including postoperative strains, primary or associated debilitating disease, hypoproteinemia, and vitamin C deficiency.

3. Although the series of cases is too small to make definite conclusions, those patients who survive secondary closure are apparently predisposed to intestinal obstruction and hernia.

NOTE.—We have encountered 2 additional cases of evisceration. These occurred through drained McBurney incisions with Weir extensions; one of whom died after secondary closure; the other recovered under conservative therapy.

REFERENCES

1. BABCOCK, W. W. Am. J. Surg., 1935, 27: 67.
2. BALDWIN, J. F. Am. J. Surg., 1934, 25: 7.
3. BELLIN, H. Am. J. Surg., 1938, 41: 494–497.
4. BETTMAN, R. B., and LICHTENSTEIN, G. M. Arch. Surg., 1936, 32: 721.
5. BOLAND, F. K., JR. South. M. J., 1936, 29: 1225.
6. CAVE, H. J. Am. M. Ass., 1933, 101: 2038.
7. COLP, R. Ann. Surg., 1934, 99: 14.
8. CRANDON, J. H., and LUND, C. C. N. England J. M., 1940, 222: 748–752.
9. DAICHMAN, I., and POMERANCE, W. J. Obst. Gyn. Brit. Empire, 1939, 37: 137.
10. DUCUING, J. Cited by Glasser.
11. ELIASON, E. L., and MCLAUGHLIN, C. Ann. Surg., 1934, 100: 1159.
12. FREEMAN, L. Arch. Surg., 1927, 14: 600.
13. GLASSER, S. T. Am. J. Surg., 1936, 32: 63.
14. GLENN, F., MOORE, S. W. Surg. Gyn. Obst., 1941, 72: 1041.
15. GRACE, R. V. Ann. Surg., 1934, 99: 28.
16. HARTZELL, J. B., and WINFIELD, J. M. Surg. Gyn. Obst., 1939, 68: 585–601.
17. HARTZELL, J. B., WINFIELD, J. M., and IRVIN, J. L. J. Am. M. Ass., 1941, 116: 669–674.
18. HESSELTINE, H. C., and BOHLENDER, G. P. Surgery, 1941, 9:40.
19. HEYD, C. G. Ann. Surg., 1934, 99: 39.
20. HINTON, J. W. Arch. Surg., 1936, 33: 192.
21. HORNER, D. A. J. Am. M. Ass., 1929, 90: 1126.
22. INGALLS, T. H., and WARREN, H. A. N. England J. M., 1937, 217: 443.
23. JENKINS, H. P. Surg. Gyn. Obst., 1937, 64: 648.
24. JONES, T. E., NEWELL, E. T., and BRUBAKER, R. E. Surg. Gyn. Obst., 1941, 72: 1056–1059.
25. KENNEDY, J. W. Am. J. Surg., 1934, 25: 512.
26. KOSTER, H., and KASMAN, L. Am. J. Surg., 1936, 31: 536.
27. Idem. Arch. Surg., 1942, 45: 776.
28. KOSTER, H., SHAPIRO, A. Arch. Surg., 1940, 41: 723.
29. KRAISEL, C. J., KASTEN, B. M., and CIMIOTTI, J. G. Surg. Gyn. Obst., 1938, 66: 628.
30. KROSS, I. Am. J. Surg., 1938, 39: 610.
31. LAHEY, F. H. J. Am. M. Ass., 1927, 89: 1735.
32. LUND, C. C., CRANDON, I. H., and DILL, D. B. N. England J. M., 1940, 223: 353.
33. MAES, U., BOYCE, F. F., and MCFETRIDGE, E. M. Ann. Surg., 1934, 100: 968.
34. MELENEY, F. L., and HOWES, E. L. Ann. Surg., 1936, 99: 5.
35. MILBERT, A. H. Arch. Surg., 1935, 31: 86.
36. NORRIS, J. D. Surgery, 1939, 5: 775.
37. PICKRELL, KENNETH, L. Johns Hopkins Hosp. Bull., 1939, 64: 195.
38. POOL, E. H. Am. J. Surg., 1931, 13: 225.
39. REID, M. R., ZINNINGER, M. M., and MERRELL, P. Ann. Surg., 1933, 98: 890.
40. SCHMITZ, H. E., and BEATON, J. H. Am. J. Obst. Gyn., Brit. Empire, 1942, 43: 806.
41. SHIPLEY, A. M. Ann. Surg., 1925, 82: 452.
42. SIGALAS, M. Evolut. med. chir., Paris, 1932, 51: 32.
43. SIMS, H. Colorado M., 1935, Sept.
44. SINGLETON, A. O., and BLOCKER, T. G. J. Am. M. A. 1939, 112: 122–126.
45. SOKOLOV, S. Cited by Jenkins, and Hartzell and Winfield.
46. STARR, A., and MASON, L. H. J. Am. M. Ass., 1933, 100: 310.
47. THOMPSON, W. A., RAVDIN, I. S., and FRANK, I. L. Arch. Surg., 1939, 36: 500.
48. WEVER, M. Cited by Glasser.
49. WHIPPLE, A. O., and ELLIOT, H. E., JR. Ann. Surg., 1938, 108: 741.
50. WHITE, W. C. Ann. Surg., 1934, 99: 34.
51. WOLFER, J. A. Surg. Clin. N. America, 1940, 20: 225.
52. WOLFER, J. A., and HOEBEL, F. C. Surg. Gyn. Obst., 1939, 69: 745–755.

PYOGENIC COXITIS

II. Indications for Surgical Treatment in Residual and Chronic Stages and End-Results of Reconstruction in 53 Patients

PAUL H. HARMON, Ph.D., M.D., Sayre, Pennsylvania, and
CARROLL O. ADAMS, M.D., Medical Corps, The United States Army

IN a previous paper which reviewed factors bearing on end-results from suppuration within the hip joint, it has been determined that the age of the patient at onset and the extent and severity of accompanying bone infection were the most important influences that were not under control of the surgeon. Similar facts have been pointed out but not thoroughly analyzed by other authors. These factors all determine the amount of bone lost and the frequency of hip joint dislocation when indifferent treatment is applied. Meticulous treatment substitutes controllable beneficial factors which partially counterbalance unfavorable factors and can modify the course of the disease in a favorable direction. Early diagnosis by joint aspiration, relief of joint distention by aspiration or arthrotomy and separation of the articular cartilage surfaces by traction, all serve to prevent, in many cases, the extreme disabling sequelae in this disease. One hundred and six patients among a larger group of 132 patients with 147 involved joints came to our attention with residual deformity or other chronic disorders. Eighty-two reconstructive surgical operations were performed upon 53 of these patients. Others were not treated surgically because the patient or his parents did not wish anything done or because the proper indications were not present. In following the histories of these patients in retrospect, it was seen that the majority of the disabling sequelae might have been prevented by the early and assiduous application of the treatment previously outlined for the acute and recovery stages.

These principles are poorly understood in many quarters and in the cases reviewed here have been applied indifferently or not at all. The orthopedic surgeon will probably continue to encounter numerous disabilities which are the sequelae of suppurative disease of the hip joint. Our review of this group of cases has been valuable in determining the incidence of certain deformities and complications that commonly result from this disorder, and, in addition, in determining which procedures are likely to yield the best results in reconstructing the deformities observed.

There are few reports in the surgical literature presenting actual experiences in the reconstruction of sufficient numbers of these cases to make an adequate record upon which further work can be based. The current impression is that years should elapse between the subsidence of acute symptoms and the performance of elective operations aimed at correcting deformity. There is no unanimity of opinion as to the most desirable end-result: a movable imperfect hip joint or a painless stable joint secured by osseous ankylosis. There are, of course, situations largely personal and occupational in nature which clearly call for bony union with complete elimination of the hip joint. These will be pointed out in a later section of this paper.

In our previous communication dealing with end-results from suppuration in the hip joint as observed with and without treatment, we found the cases to fall naturally into three groups. There were important differences in the course and outcome from suppuration between these groups which seemed to be conditioned largely by the extent of bone suppuration and by relative proportions of bone and

From the Division of Orthopedic Surgery, The Department of Surgery, The University of Chicago, and from the Division for Handicapped Children of the Illinois State Department of Public Welfare.

Read in part before the American Academy of Orthopedic Surgeons, Memphis, Tennessee, January 18, 1939; before the Chicago Orthopedic Society, October 9, 1936; and at a meeting of the Philadelphia Orthopedic Society, December 9, 1941.

TABLE I.—RESULTS OF TREATMENT

Condition and operation	Cases	Number of satisfactory results	Percentage of satisfactory results
1. Continued purulent drainage			
Sequestrectomy for all or a portion of the femoral head	8	7	87.5
Radical excision of the ilium for chronic osteomyelitis	9	8	89.0
Hip joint disarticulation	3	2	66.6
2. Malposition at the hip			
Subtrochanteric osteotomy at the fused hip	12	12	100.0
Subtrochanteric osteotomy in the presence of a movable hip	3	3	100.0
Transplantation of the greater trochanter	3	3	100.0
3. Unilaterally unstable hips (dislocated or dislocating)			
Surgical arthrodesis	3	3	100.0
Acetabular shelf operations	7*		85.7
Reconstruction by longitudinal osteotomy	1	1	100.0
4. Unilaterally ankylosed hips			
Jones pseudoarthrosis operation	3	0	0.0
Fascial arthroplasty	5	1	20.0
Vitallium cup arthroplasty	1	1	100.0
5. Painful hips			
Surgical arthrodesis	5	5	100.0
Fascial arthroplasty	None		
6. Unequal leg length			
Femoral lengthening	2	0	0.0
Femoral shortening	6	6	100.0
Epiphyseal arrest operation			
Single (lower femur)	8		
Multiple	2	2	20.0
7. Residual deformities from bilateral suppurative coxitis†			
Bilaterally movable	2		
Bilaterally movable, one side unstable	2		
One ankylosed in acetabulum with contralateral hip dislocated	3		
Bilateral solid bony ankylosis	8		
Total cases	15		
Unilateral fascial arthroplasty for bilateral ankylosis	1	0	0.0
Jones pseudoarthrosis operation	2	0	0.0

*Movable hip, 5; subsequent stiffening, 1.
†No treatment was attempted in this group, in general, because they were observed before arthroplasty became universally adopted.

cartilage about the hip. The outcome appeared to be independent of the infecting micro-organisms, except as conditioned by the factor of extent of involvement. These groups were: (1) from 0 to 3 years of age, inclusive; (2) from 4 to 12 years of age; and (3) an "adult" group 13 years of age and over. It was seen in the first two groups, especially in the second group, which included the bulk of cases, that a movable and painless hip often resulted and was a desirable end-result, even though a variable amount of bone of the femoral neck was lost through suppuration and even though osteoarthritis might supervene three decades later. A stable fused hip, especially if superior displacement and dislocation were prevented by traction, was the usual outcome in adults and in certain cases in the juvenile and adolescent groups. This outcome appears likewise desirable. Indeed, in the older cases, if bony union did not occur with elimination of the joint, pain was the usual outcome. Surgical treatment is often indicated to eliminate pain. We have found it convenient to retain the classification of cases according to age in considering the indications for, and end-results from, operative treatment of the residual deformities met with in this group of cases, since there was a lag between the acute stage of the disease and the time when the patients sought advice for residual deformity. There were few cases encountered in the infantile age group in which disability and deformity indicated surgical treatment. Because of the large amount of cartilage in the infantile upper femur, suppuration at this early age is characterized by a benign, immediate course and an outcome of an unstable hip. Most of the cases from the infantile group (15 of 18, or 83 per cent) with unilateral involvement did not present themselves for reconstruction until an average of 8.7 years after the acute stage. Of the 3 remaining cases 2 were considered in a previous publication describing a hip reconstruction operation suited to these very young children presenting dislocating hips, while the third upon whom a shelf operation was performed at the age of 1 year (Case R.V., Table II) is considered in a later section of this paper.

CONTINUED PURULENT DRAINAGE

Following the subsidence of the acute phase of pyogenic coxitis and its accompanying acute or subacute osteomyelitis, it is the rule that the incision made for drainage closes promptly. If drainage persists from this region or

TABLE II.—RESULTS OF SHELF OPERATIONS FOR SUPPURATIVE COXITIS IN JUVENILES

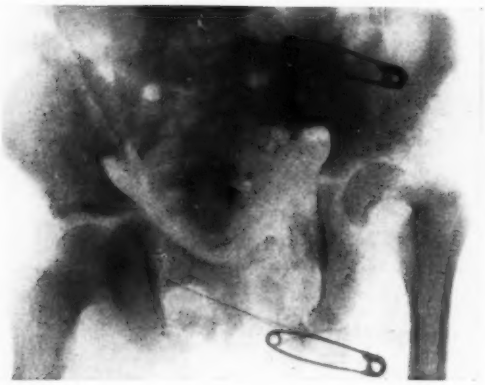
Patient	Age at onset (yrs.)	Present age (yrs.)	Time (yrs.) between acute disease and shelf operation	Shortening (cm.) (without leg equalization procedures)	Time (yrs.) between operation and last observation	Result after years
J. G.*	0.5	15	6.5	6	8	Gait good. Trendelenburg negative. Passive flexion 60°; tendency to external rotation; disability solely due to leg length inequality
R. V.*	0.5	10	0.5	0	7	Gait good. Walks without a limp. Trendelenburg negative. Passive flexion 90°. Circumduction 10°
R. E.	0.5	18	7.0	6**	9	Hip totally stiff from fibrous ankylosis. Gait excellent
O. C.	0.5	17	6.0	5	7	Gait fair. Trendelenburg positive. Passive flexion 40°. Hip stable
J. C.	1.0	17	7.0	2	10	Gait good. Slight flexion deformity. Passive flexion 60°. Adduction, abduction, and circumduction 10°
D. L. P.*	2.0	15	10.0	4	6	Stable hip. Trendelenburg negative; 60° passive flexion. Roentgenograms show advanced changes with flattening and sclerosis in femoral head
A. Z.*	3.0	23	12.0	9	8	Passive flexion 90°. Abduction-adduction 10°. Gait poor due to inequality in leg length. Patient refused surgical treatment of the latter condition

*Denotes tibial peg shelf operation.
**Shortening decreased to 2 cm. 3 years after distal femoral epiphyseal arrest.

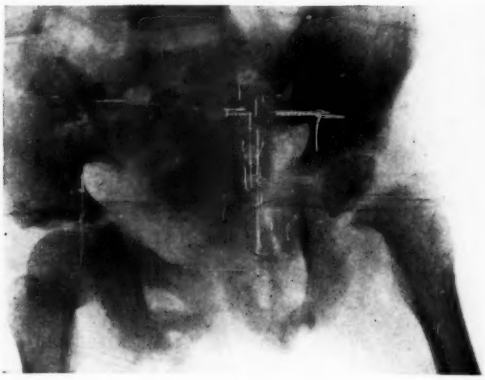
from sinuses about the pelvis or in the thigh for more than 4 to 6 weeks, the surgeon should search for the causes of continued drainage, as he should also do before any reconstructive procedure is done. Occasionally patients are encountered who have had unsatisfactory primary treatment and drainage has persisted for years. Roentgenograms and injection of sinus tracts with opaque materials are the procedures which will yield the most valuable information. The common causes of continued drainage in chronic osteomyelitis are well known: sequestrated bone, chronic bone abscesses, and epithelialized sinuses.

In connection with pyogenic coxitis, certain special causes of continued drainage are met which are the special modifications of the causes named; epiphysiolysis of a portion or all of the femoral head is common, especially when traction has been neglected or applied in an indifferent fashion in the acute stages. The detached and dead femoral head, or a portion of it, may remain as a cause of continued drainage. A dead and separated head was encountered in 8 patients in our series. The results of removal are usually dramatic, drainage usually ceasing in a few days. In a single case in our list, it appeared that removal of a portion of the sequestrated femoral head caused local reactivation of suppuration with contiguous extension into the supra-acetabular zone and into the femoral neck. This occurred in a patient who appeared to have little general resistance to suppuration and who later died of local extension and generalized metastatic pyemic abscess. If epiphysiolysis occurs in a suppurative joint which has not had to be drained and about which there are no sinuses established, or if aseptic necrosis of the capital epiphysis occurs without its detachment, the dead segment may be allowed to remain for a few months, to see if it will be transformed and incorporated into the pelvofemoral block of bone which results. The cartilage over the femoral head rapidly disappears from the necrotic femoral head. It appeared that we were successful in 1 case (Fig. 1) in maintaining motion in a hip and in securing union between a separated femoral head and the metaphysis. This was a special instance in which the suppuration was of low grade and in which an incision made for drainage had been healed for several weeks. The methods employed in securing this result would be contraindicated except when the suppuration is of low grade or definitely subsiding.

Extensive osteomyelitis in the pubis, ischium, or ilium is a frequent cause of continued drainage. Since the clinical course from osteomyelitis of the bones of the pelvis is different from that in the long bones, adequate involucrum formation being a rarity and the indications and methods for operation not as well understood as in the case of the long bones, some of the facts concerning pelvic



a



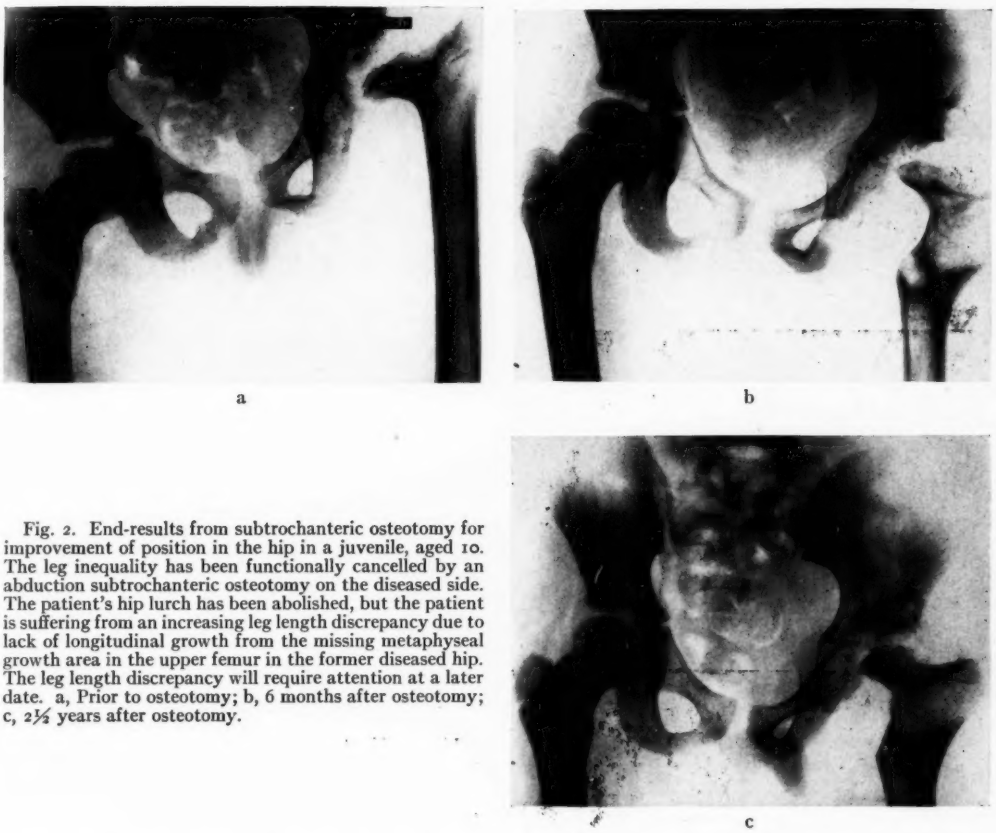
b

c

Fig. 1. Roentgenograms demonstrating epiphysiolysis with subsequent reduction, internal fixation, and union with head, in a juvenile patient, aged 8. a, Demonstration of separation of epiphysis with external rotation of distal fragment. b, Reduction. c, View 5 months after internal fixation with threaded stainless steel wires.

osteomyelitis will be summarized in this place. This subject has been dealt with in recent years in the writings of Badgley, Young, Milch, and Kulowski. Pelvic, trunk, and thigh abscesses are produced especially from osteomyelitis of the ilium which is the bone most frequently involved. Osseous foci above the iliopectineal line give rise to either internal iliac abscesses, which often burrow into the thigh, or to multiple draining sinuses about and above the trochanters and sacroiliac joints, depending upon whether the bone foci discharge internally or to the exterior. Pelvic abscesses of various types may develop. Roentgenograms in this chronic stage reveal either sclerosis of a segment of the ilium or the especial mottled appearance which signifies the presence of multiple medullary abscesses and the presence of numerous small sequestra, a situation that is best treated by partial or complete excision of the ilium. The tremendous thickening of this bone and the extent and distribution of abscesses and multiple sequestra from the internal and external tables of the pelvic bones cannot be appreciated except by operative visualization of such lesions. Roentgenograms seldom demonstrate these changes clearly.

Excision of the major portion of the ilium was undertaken 9 times in our cases. Excision of a longitudinal portion of the ischium was done once. The result from the latter was ex-



a b c

Fig. 2. End-results from subtrochanteric osteotomy for improvement of position in the hip in a juvenile, aged 10. The leg inequality has been functionally cancelled by an abduction subtrochanteric osteotomy on the diseased side. The patient's hip lurch has been abolished, but the patient is suffering from an increasing leg length discrepancy due to lack of longitudinal growth from the missing metaphyseal growth area in the upper femur in the former diseased hip. The leg length discrepancy will require attention at a later date. a, Prior to osteotomy; b, 6 months after osteotomy; c, 2½ years after osteotomy.

cellent (criterion: the elimination of drainage), as was the case in chronic osteomyelitis of the ilium in 80 per cent of cases. Continued drainage was the result in 1 case, and the opportunity was not afforded to investigate the cause further. It is possible, in view of the generally excellent results in eradicating drainage by radical iliectomy, that a better outcome might have followed further treatment. Badgley reported that in 17 of his 20 cases (85 per cent) patients were cured (drainage eliminated).

Disarticulation of the hip joint should receive more consideration in the treatment of persistent suppuration of the hip joint in adults in the presence of osteomyelitis in the upper half of the femur. This is particularly true in the instance of acute spread to this zone by direct extension or by the blood stream in adults, since they form involucrum poorly or not at all and this procedure is the only means of eradicating a chronic suppurative focus which may later threaten the life of the patient. This operation was done in 3 of our cases (Table I). A fatality occurred in 1 patient several months after the operation since spreading gangrene occurred in the wound, and metastatic suppurative foci developed elsewhere. When the indication is clear, disarticulation should be carried out at once, rather than as a last-minute attempt to save the patient's life.

MALPOSITION AT THE HIP

Attempts to establish the correct relation between the pelvis and the upper femur or the

a

b

c

d

e

Fig. 3. Short term end-results in 2 juvenile cases in which hips have been stabilized by a supra-acetabular shelf. a, b, c, Patient, R.V., (Table II), aged 1½ years at time of shelf operation—a, preoperative; b, upon removal from cast, 12 weeks after operation; c, 1½ years after operation. d, and e, Patient J.C. (Table II), aged 8 at time of shelf operation—d, before operation; and e, 2 years after operation.

remnants of the femoral stump should receive first attention during the stages of acute suppuration. The "natural" and "comfortable" attitude of flexion and adduction should be combated in the acute stages by traction or casts. The question of pathological dislocation in one or both hips in suppurative hip joint disease will be dealt with in the later section in which the problem of bilateral hip joint suppuration is discussed.

Poor position at the hip is usually associated with an ankylosed joint which was, through poor initial treatment, allowed to stiffen in malposition. In the growing child or in those allowed to walk upon the leg without support when the new bone bridging the joint is not firm, an acquired malposition develops usually in flexion and adduction. Ankylosis in gross abduction is occasionally the result of disregard of position during the acute stages. Up to 30 degrees of abduction, if no flexion is present, may be desirable, especially when the involved femur is slightly shorter or has lost some bone at the hip through dislocation or

suppuration. Abduction of that degree is often the partial or complete aim of subtrochanteric osteotomy for positional correction, since every 30 degrees of abduction is equal functionally to an increase of 1 inch of leg length.

In the absence of a movable hip, only roentgen study of the pelvis can help in the decision to osteotomize the movable femur for positional correction, or to perform a surgical arthrodesis. The special indications in this situation for surgical arthrodesis will be discussed in a later section dealing with the end-results from this procedure. In general, pain and an unstable hip are the usual indications for it. The indications for subtrochanteric osteotomy for positional correction when a movable hip is encountered in the residual deformity from suppurative hip joint arthritis are: (1) to increase hip joint stability when incipient dislocation is present—this is usually associated with a short or missing femoral neck remnant: (2) to obtain minor degrees of functional leg length increase (up to one inch).

The presence of hip joint stability or the probable result of hip joint stability is a prerequisite to the performance of a subtrochanteric osteotomy in the presence of a movable hip. (Figure 2 is an illustrative end-result.) It should be stated that osteotomy in the subtrochanteric region to improve position is the operation that is most frequently indicated to remedy the deformities resulting from the disease. At the same time the results are satisfactory (100 per cent in our series of 15 operations). If it can be postponed in the growing child until the age of 12 or 14 years, the likelihood of having to repeat the osteotomy later for recurrence of deformity, which is a common result in younger children (up to 10 years), can be avoided.

Listed with these operations in Table I are 3 cases in which "transplantation of the greater trochanter" was performed. When the mechanics of muscle pull in the presence of an incipient or dislocated hip are considered, the downward shift of the greater trochanter is the mechanical equivalent of performing an abduction osteotomy in the presence of a movable hip. The author is of the opinion (based upon the results in these 3 cases and in other cases in which the operation was performed following the shelf operation for congenital dislocation of the hip) that gait is not improved following it. The operation of trochanteric shift makes less the likelihood of osseous displacement of the upper femoral fragment out of the acetabulum. For the residual deformity associated with a short femoral neck remnant in this condition, it is our opinion that simple abduction osteotomy in the presence of a movable hip, is the operation of choice, being simple and easier to perform and more certain in outcome. This is likewise the opinion of Moore, reporting upon the same group of juvenile patients with residual movable hips following suppurative hip joint disease. It should also be borne in mind that many of these patients will probably develop painful hips in later years and require a procedure for the elimination of pain. The period of follow-up on our juvenile pa-

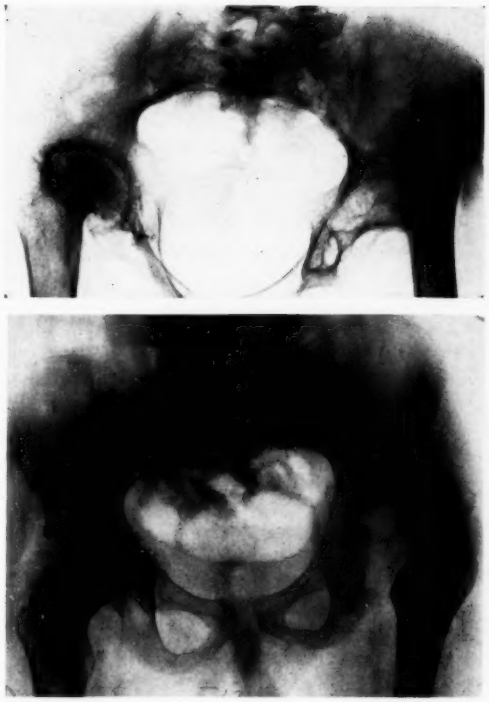


Fig. 4. Illustration of the extensive deformities in 2 cases of bilateral suppurative arthritis of the hip.

tients was not sufficiently long to carry them into middle age in order to determine this point statistically. However, 5 patients in the adult group were treated by surgical arthrodesis for painful hips, all cases of osteoarthritis secondary to proved suppurative arthritis (see later section on painful hips).

UNILATERAL HIP JOINT INSTABILITY

Complete instability of the hip is the result of preservation of motion following purulent destruction or sequestration of the head and subsequent loss of the femoral neck by "absorption" which in many cases is the result of pressure and necrosis. The possessor of such a unilateral unstable hip has an unsightly "hip lurch" produced by pelvic sag when the weight is supported upon the unstable lower extremity. The result to be achieved by treatment is hip stability. In the adult, the only means of obtaining this result is surgical arthrodesis of the hip, which is performed following placement of the dislocated hip at the level of the acetabulum to restore leg length lost by the dislocation. This operation was performed under this indication in this age group three times in our cases, all with marked improvement in gait.

In the juvenile group, the shelf operation is the procedure of choice. It can be performed 6 months after the cessation of drainage, provided there are no residual bone markings of associated osteomyelitis, in which case the operation had best be postponed several years until these are eliminated or become suited for operative intervention (see section on operation in ankylosed hips). Table II gives the results from the shelf operation as performed on 7 patients in this age group. The results were good (stable hip and "good" gait) in 5 of the 7 cases (71.3 per cent). In a 6th case the outcome was excellent but the object of the operation failed as osseous ankylosis developed. The end-results justify the employment of the operation to secure a movable and stable hip in juveniles with unilaterally unstable hips. The number that will develop pain at a later date is unknown.

In a previous report we have presented the result in an instance of longitudinal osteotomy for reconstruction to remedy the dislocating hip in an infant. L'Episcopo has presented the results from a similar operation in children in the juvenile group. It should be noted in Table II (Case R.V.) that the shelf operation was performed on a child 1 year of age, 6 months after suppuration occurred, with a good 7 year end-result (Fig. 3). The patient was no longer available for follow-up after this time. Discrepancies in leg length that become apparent in later years often mar an otherwise excellent result at the hip. This again brings out the necessity to follow these juvenile patients to maturity and to carry out an appropriate procedure for leg equalization.

UNILATERALLY ANKYLOSED HIPS

One of the best end-results that may be secured from suppuration within the hip joint is a stable hip obtained by osseous ankylosis, especially if there has been no shortening due to loss of bone at the hip. However, the orthopedic surgeon is continually being confronted with young adults, formerly the victims of suppurative hip joint disease, who wish to obtain a movable hip. If there is much evidence of bone markings in the roentgenogram, due to small abscesses or sequestra in or near the line of proposed osteotomy to mobilize the femoral head, or if there has originally been extensive osteomyelitis contiguous to the hip joint, no attempt should be made to secure a movable hip because of the danger of reactivating the former bone infection. Davis has published an important study dealing with the criteria to be observed in preventing recurrence of infection after elective operations in cases of healed suppuration in bones and joints. He found that "it is possible to anticipate the recurrence of infections from the roentgen appearance." There were no recurrences of infection in operations on gonococcal joints, even if the reconstructive operation be executed within 6 months of the subsidence of the disease. The period of quiescence had little to do with conditioning recurrences. The recurrence rate was 13 per cent in mobilizing operations upon former septic joints, which was quite similar to the recurrence rate of 10 per cent found by Hallock. The recurrence rate was lowered to 2.5 per cent when the operation was done in

healthy bone but "near" the former site of suppuration. This "recurrence rate" is likely to be lowered more with the local and systemic use of the sulfonamides.

Most of the operations to be reported in this section were done before the current period of interest in foreign body cup arthroplasties. The end-results obtained must then be considered as representative of procedures that are not at present the operations of election. The outcome from the Jones pseudoarthrosis operation was re-ankylosis in all 3 hips. Judged by modern standards, this procedure is a makeshift operation. Fascial arthroplasty was performed on 6 patients, all adults. Only 1 (20 per cent) presented a satisfactory end-result (adequate motion, no pain and a stable hip). The cause of the unsatisfactory end-results was aseptic necrosis and absorption of the reconstructed femoral head in 3 cases and reankylosis in 2 cases. We performed a vitallium cup arthroplasty in 1 instance with a very satisfactory end-result.

There are no statistics in the literature on hip arthroplasty as applied to the residual form of suppurative arthritis of the hip, except those from Steindler's clinic, reported by Fuiks in which "good" and "fair" results were obtained in 77 per cent of 9 cases. These were not analyzed in detail. Steindler presents statistics summarized from the literature showing that "good" and "fair" results from hip joint arthroplasty aggregate 64 per cent. Hallock and others have commented upon the frequency with which re-ankylosis occurs in attempts at arthroplasty upon patients who formerly had suppurative hip joint disease.

The advent of the foreign body cup, which has simplified the technique of hip joint arthroplasty, has again reopened this field. The use of vitallium cups, which are opaque to roentgenograms, does not make it possible to follow osseous changes in the remodeled femoral head. The frequency of collapse of the neck fragment following arthroplasty for the residual from suppurative arthritis of the hip makes it desirable that an attempt be made to follow any changes that may occur following cup arthroplasty. The use of nonmetallic cups of methacrylate plastic makes such observations possible. As yet, no end-results in sufficient numbers following vitallium cup arthroplasty for this condition have accumulated.

The problem of attempting to secure a satisfactory result from arthroplasty of the hip in deformities from suppurative arthritis should be approached in each case upon an individual basis. In general, if the patient has a stable hip, ankylosed in good position, he should be discouraged from attempting to secure motion in the hip, as the outcome from arthroplasty is distinctly a gamble in a single case. This fact, the technical aspects of the operation, and the necessity for vigorous postoperative exercise, should be understood by the patient before he submits to the operation. The specific conditions that should be met before performing hip arthroplasty for this disorder are:

1. The patient should enthusiastically desire the operation and be willing to sacrifice enough energy and time to comply with the vigorous postoperative schedule.
2. The patient should always be under 50 years of age and in good general health.
3. No draining sinuses can be present.
4. Roentgenograms must demonstrate the absence of osteomyelitic changes at the former hip joint site and in neighboring bones. Magnified views should be carefully examined for small bone abscesses and sequestra.
5. The patient's occupation should be a "light" or sedentary one. If he is a laborer or employed in an occupation in which he must stand or walk many hours a day, an ankylosed hip in good position is preferable.
6. Gross distortion of bone in the pelvis and upper femur must be absent and there must be no fibrosis or extensive atrophy of the muscles about the pelvis.

A patient with bilaterally ankylosed hips is considered by some to be especially desirable for arthroplasty of the hip. This condition, as well as original involvement of both hips, followed by ankylosis of one, is neither an indication nor a contraindication for the operation, as individual evaluation upon the basis of the conditions enumerated above is of greater importance.

PAINFUL HIPS

When motion is preserved in the hip joint, the site of alterations produced by previous

disease, it is likely that pain with or without osteoarthritis will develop in later years. This condition was observed in 5 adults among our cases. All were treated by operative fusion of the joint with satisfactory results in each case (painless and stable hip). The disadvantage to the patient is the usual one of a stiff hip, i.e., difficulty in sitting and extra strain in the low back area. These disadvantages must be balanced against the patient's current disability from hip pain. In all of our 5 cases gait was improved because of relief from pain. No arthroplastic procedures were performed upon the indication of pain. The relief from pain, now known to be afforded by foreign body cup arthroplasty, would indicate the use of these newer methods before arthrodesis is resorted to.

UNEQUAL LEG LENGTH

Functional inequality of the lower limbs must be constantly evaluated in these patients. These factors are at work: superior displacement in the unstable hip, loss of bone due to suppuration and shortening due to malposition in flexion and adduction. Roentgenograms of the pelvis and physical findings are both essential in evaluating these 3 factors. The first and last can each be dealt with by appropriate operative means. Direct measures designed to equalize leg length are sometimes indicated. Fourteen patients had surgical operations (leg shortening, leg lengthening or epiphysiodesis for arrestment of longitudinal growth) performed upon them (Table I). Surgical leg equalizations were recommended but refused by the patients in 12 additional cases. Of these three procedures, it would appear from our results that diaphysectomy for leg shortening was the operation that yielded the desired end-result consistently. However, it should be pointed out that some of the epiphyseal arrest operations were performed upon older adolescents that are now known to have been operated upon too late to expect sufficient growth cancellation. The knowledge of this factor should enable better selection of cases for the epiphyseal arrest operation. Leg shortening, on the other hand, is an exact procedure, the results of which are obtained quickly and with certainty. Space cannot be given here to a detailed discussion of the indications and results from these 3 surgical procedures. The reader is referred to original descriptions and reviews of the subject.

RECONSTRUCTION OF DEFORMITIES FROM BILATERAL SUPPURATIVE ARTHRITIS OF THE HIPS

Similar to the state following unilateral suppuration in the hip, only half of our cases falling into this division presented bilateral osseous ankylosis of the hips (8 of 15, or 53.3 per cent). Ambulation in these latter cases, which is accomplished by alternately pivoting on the lower extremities, had resulted in a fairly good gait, considering the disability. Among the 8 ankylosed cases, vitallium cup arthroplasty was carried out bilaterally in 2 cases with good results. The adolescent age of these patients undoubtedly favored the result, since such a good function is seldom obtained in adults with bilateral ankylosed hips from any cause.

Of the 7 other cases, only 2 were satisfactory, presenting stable and movable hips that did not need consideration for reconstruction (Fig. 4). It is highly probable that these 2 cases will develop osteoarthritis in succeeding years because of the slight to moderate deformity in the femoral heads. The 5 remaining cases presented appalling deformities (Fig. 4) grouped as follows: bilaterally movable hips with unilateral "instability of gait" but without dislocation, 2 cases; 1 hip ankylosed in acetabulum by bone associated with dislocation of the other hip, 3 cases. No operative procedure was attempted in the 2 cases with movable hips with gait instability in one hip.

As was pointed out for the acute stage in the previous paper, it is desirable to reduce the dislocation when present. Badgley's experience was that reduction in 17 cases when dislocation occurred resulted in 8 cases of ankylosis and a "satisfactory" result in 8 others (50 per cent or more of motion). Approximately the same percentage of ankylosis (60 per cent) occurred after reduction of dislocation in our acute cases presenting this complication. Bilateral dislocations, as a complication of the acute stage, do not alter the desirability of reduction at this time since

there is better than an even chance that one hip will remain in place and will have greater than half a normal range of motion. It is, of course, highly probable that later, degenerative changes leading to osteoarthritis in one or both hips will follow.

ANALYSIS OF OBSERVATIONS

No dogmatic statement can be laid down as to the optimum age at which reconstructive procedures should begin. This, of course, depends directly upon the patient's age at the onset of the acute phase and the rapidity and effectiveness of control of the initial suppuration. In the case of long continued discharge from deep sinuses, the measures aimed at closing these, largely a search for, and correction of, elimination of mechanical causes (sequestra, epithelialized sinuses and chronic osseous abscesses), are quite effective. The results obtained in this series are better than the average seen in this type of patient in all age groups, since the majority of our patients were adolescents and young adults many of whom had had the onset of the acute disease several years earlier. In a few months after subsidence of the acute phase, measures can be undertaken to eliminate discharge from draining sinuses that promise not to close otherwise. After elimination of mechanical causes, as discussed in the first section of this paper, the daily instillation of a stable 20 per cent suspension of the microcrystals of sulfathiazole hastens the closure in cases in which the staphylococcus is the infecting microorganism. Sulfanilamide powder or solution can be similarly used.

Reference to Table I shows that the procedures used in reconstruction of the single hip damaged by suppuration are highly successful in juveniles. The difficult problems dealing with plastic procedures about such a damaged hip yield good results in a high percentage of cases, if performed during the last half of the first decade of life or during the early part of the following years. In adolescents or young adults, these plastic operations, including the acetabular shelf, do not give satisfactory results largely because of subsequent pain. Indeed, it must be kept in mind that a certain number of these operations performed upon juveniles will, after the passage of many years, develop pain, and will then have to have treatment directed toward that symptom. However, the fact of the fair incidence of satisfactory results that are relatively permanent warrants continuation of these reconstructive procedures.

Malposition at the fused hip should not receive surgical attention until after the approximate age of 12 to 13 years, unless the malposition is grossly exaggerated, when it may be necessary to correct it earlier by osteotomy. However, it should be remembered that osteotomy at earlier ages is seldom a permanent correction as a portion or all of the deformity will recur and need a later correction. Osteotomy in the presence of a movable hip is not subject to the same rigid age limitations, as this is usually done to increase hip stability. In the very young patient (under 3 years) special longitudinal osteotomy can be done to create an articular surface for the upper femur when the damage to the acetabulum is minimal. All these types of osteotomies lead to a uniformly good result, especially when surgical correction is performed for any associated leg length inequalities.

In general, surgical stabilization of slightly movable hips and positional correction in those already naturally ankylosed by the acute disease yield better permanent results in terms of painless extremities serviceable in weight-bearing than arthroplastic attempts to secure a movable hip. Indeed, a number of hip joint arthroplastic procedures were unsatisfactory when performed upon hips ankylosed as the result of suppurative joint disease. Subsequent collapse of the newly formed femoral head was the chief cause of failure. This complication arose because of the altered vascularity produced by sclerosis of this portion of the bone. Since this is a defect in the bone upon which the surgeon is called on to operate, this factor is not under his control and at the same time makes it improbable that the newer types of foreign body cup arthroplasties will yield radically different results when applied to unselected cases.

For the equalization of leg length, the bone shortening operations yielded uniformly satis-

factory results in our hands. The epiphyseal arrest operations that were performed were largely done upon adolescent girls and were performed too late, since at that time it was not fully appreciated that longitudinal growth of the long bones in girls often ceases as early as 11 to 13 years. Proper selection of cases would undoubtedly lead to better results in the application of this operation. However, since the leg shortening operation is an exact procedure, the correction being obtained at once, it appears to be the operation of election to be performed for this purpose. It can be applied in the growing child in the latter half of the growth period, provided prolonged previous observation has established the fact that the leg length discrepancy is not a progressive one.

The least satisfactory end-results were seen in patients presenting bilateral deformities from acute involvement of both hips. Since these patients were seen before the modern era of arthroplasty, little treatment was attempted in them.

SUMMARY AND CONCLUSIONS

A review of the end-results from surgical reconstruction of the residual deformities encountered in 53 patients who previously had suffered from acute suppuration within the hip joint is presented.

Measures aiming at eliminating chronically discharging sinuses and those carried out upon the single damaged hip yielded, as an average, satisfactory results in more than 80 per cent of cases.

Positional correction of the single ankylosed hip, subsequent ankylosis of the painful hip, and certain plastic operations that can be executed upon juveniles are more satisfactory than the arthroplastic procedures that aim to confer motion on an already ankylosed hip that has resulted from bone suppuration.

Patients that have bilaterally damaged hips, the sequelae of the condition, are an appalling group of cases that do not radically change their status following the surgical procedures that can be performed upon them. Occasionally, arthrodesis of a single unstable and dislocated hip may be indicated in this group of patients. This group of patients needs further intensive study.

REFERENCES

1. Badgley, C. E. Arch. Surg., 1934, 28: 83.
2. Badgley, C. E., Yglesias, L., Perham, W. S., and Snyder, C. H. J. Bone Surg., 1936, 18: 1047.
3. Chambers, L. A., Harris, T. N., Schumann, F., and Ferguson, L. K. J. Am. M. Ass., 1942, 119: 324.
4. Davis, J. B. Arch. Surg., 1940, 41: 1426.
5. Fuiks, D. M. Arch. Surg., 1938, 36: 386.
6. Hallock, H. Surg. Gyn. Obst., 1939, 68: 106.
7. Harmon, P. H. Pennsylvania M. J., 1941, 45: 27.
8. Idem. J. Bone Surg., 1942, 24: 576.
9. Idem. Surg. Gyn. Obst., 1943, 76: 347.
10. Harmon, P. H., and Adams, C. O. Surg. Gyn. Obst., 1944, 78: 371.
11. Harmon, P. H., and Krigsten, W. M. Surg. Gyn. Obst., 1940, 71: 482.
12. Hatcher, C. H. Paper read at meeting of the American Orthopedic Association, Buffalo, New York, June 7, 1939.
13. Hopkins, H. H., and Zuck, F. N. Med. Bull. Veterans Admin., 1938, 15: 1.
14. Kulowski, J. Arch. Surg., 1937, 35: 571.
15. Idem. Surg. Gyn. Obst., 1939, 69: 312.
16. L'Episcopo, J. B. J. Bone Surg., 1936, 18: 737.
17. Milch, H. J. J. Bone Surg., 1935, 17: 166.
18. Moore, B. H. Paper read at convention of American Academy of Orthopedic Surgeons, Memphis, Tennessee, January 18, 1939.
19. Phemister, D. B. J. Bone Surg., 1933, 15: 1.
20. Rehn, E. Arch. klin. Chir., 1934, 180: 395.
21. Smith-Peterson, N. M. J. Bone Surg., 1939, 21: 269.
22. Steindler, A. Orthopaedic Operations. Springfield, Ill.: C. C. Thomas, 1940.
23. White, J. H. J. Bone Surg., 1935, 17: 597.
24. Wilson, P. D., and Thompson, T. C. Ann. Surg., 1939, 116: 992.
25. Young, F. Surg. Gyn. Obst., 1934, 58: 986.

HEMORRHAGIC SHOCK

The Relative Effect of Saline, Washed Red Cells, and Heparinized Plasma in Dogs

F. W. McKEE, M.D., C. F. LAYCOCK, M.D., T. G. MARTENS, M.D., and R. J. NICHOLL, M.D., Rochester, New York

THESE experiments were undertaken in view of the recent interest regarding "hemorrhagic shock" and related war problems. An attempt was made to devise a method which could be easily duplicated for the production of this condition. We shall report the effect of saline, plasma, and washed red cells on dogs which were in a state of posthemorrhagic circulatory collapse, commonly referred to as shock. Investigators have used many methods for the production of shock and have tested many different solutions for its treatment. It is well known that saline has a temporary sustaining effect on humans and animals in shock. In both military and civilian practice, whole blood or plasma has been accepted as the treatment of choice in shock. Plasma is generally used because of its ease of preparation, storage, transportation, and administration without fear of serious untoward reactions. Washed red cells have previously been considered a rather poor blood substitute by other workers in spite of the fact that the majority of the effects of hemorrhagic shock can be explained on the basis of anoxia. The literature in this field has become quite voluminous, and only a few pertinent reports are mentioned.

Rossius (1925) stated that washed red cells exerted about the same resuscitating effect as saline in the treatment of acute hemorrhagic shock. Hoitink (1935), using clinical evidence for determining a state of shock, claimed that normal saline was as effective as any of his test solutions, which included simple and complex crystalloid solutions. Magladery and associates (1940) believed that serum and plasma were effective in posthemorrhagic shock in dogs, and stated that 40 per cent or more of the original blood volume removed must be restored. He also stated that red cells are quite effective, but that the red cell volume is more important than the oxygen carrying power. Buttle and associates (1940) found, in cats, that the red cells suspended in saline were less effective than plasma, serum, hemoglobin-Ringer's, or gum-saline solutions. Muirhead and associates (1942) showed that plasma administration caused hemodilution and also stated that complicating factors were introduced by the use of citrate as an anticoagulant and by general anesthetic agents. The recent work of Ivy and coworkers (1943), on dogs, demonstrated that plasma was an effective blood substitute, but he did not use red cells in his series. Ivy's work also serves to show that it is important to administer the replacement solution rapidly and as soon as possible following the bleeding. This was also pointed out by Magladery.

When the term "shock" is used today it means different things to different groups of workers, and the term should always be defined as clearly as possible. The important thing is that each investigator define what he means by the term "shock" or "hemorrhagic shock" in the experiments under consideration. There is some question as to the advisability of using the term "acute hemorrhagic shock," for Wiggers and associates (9, 10, 11, 1942) would reserve this term for an irreversible condition in which reinfusion of the animal's own blood brings about only temporary relief. The animals subsequently died. We see no reason for the reservation of the term "shock" for this condition. Ebert and associates (1942), using similar technique, were unable to duplicate this irreversibility. They kept dogs at a low blood pressure for 12 hours with subsequent recovery of all animals.

From the Department of Pathology, The University of Rochester School of Medicine and Dentistry, Rochester, New York.

In the final analysis, the efficacy of a blood substitute depends on its ability to maintain a satisfactory circulatory state. Such a test solution may be considered adequate if animals receiving it survive without deleterious effects; whereas, untreated, they succumb.

METHODS AND MATERIALS

All dogs used in these studies were healthy, male and female animals. They were observed for at least 2 weeks before being used and were fed the standard kennel diet of hospital scraps reinforced with Purina dog chow. Most of the animals which survived were used a second time after a period of 3 to 6 weeks to permit blood constituents to return to normal.

Precisely the same technique was used in all animals. The only anesthetic used was procaine hydrochloride 1 per cent, about 5 cubic centimeters being injected into the skin and subcutaneous tissues over the femoral triangle. The femoral artery and vein were then cannulated with appropriately sized glass cannulas. Two drip bottles connected with a Y tube were hung about 2 feet above the dog and were attached to the cannula in the femoral vein by a rubber tube. One bottle contained 0.9 per cent saline solution and was used for a slow drip to keep the cannula open, about 3 to 5 cubic centimeters being administered in this way during the experiment. The perfusion and transfusion fluids were given rapidly from the second bottle with the aid of positive pressure.

When the primary bleeding from the femoral artery had decreased to a slow drip, the collecting flasks were changed and the dog was immediately perfused with 23 cubic centimeters per kilogram body weight of 0.9 per cent saline. This caused an increase in blood flow from the femoral artery for a short period (Table heading, "Volume removed after perfusion"), which then subsided to a slow drip. At this point the bleeding was stopped and the artery was ligated with silk. The dogs were then in profound shock as evidenced by extensor rigidity, loss of sphincter control, air hunger, and in some cases, apnea. The *volume of the primary bleeding* before the perfusion was immediately *replaced by the blood substitute* and the vein was ligated. A small amount of 5 per cent sodium sulfathiazole ointment was placed in the wound, and the incision was closed with silk. The operating time was 30 to 40 minutes, the bleeding time 2 to 3 minutes, the perfusion time 1 to 2 minutes, the post-perfusion bleeding time 4 to 5 minutes, and the transfusion time 1 to 2 minutes.

The primary bleeding not followed by perfusion produced shock in about one-half of the dogs, but none of them died. Therefore, we added the perfusion procedure. An empirical figure of 23 cubic centimeters of 0.9 per cent saline per kilogram body weight was reached, after finding that when 25 cubic centimeters saline per kilogram was used, immediate death followed; whereas, with 20 cubic centimeters saline per kilogram, death was not produced in any of the animals.

The blood was collected with sterile flasks and rubber tubes. The operating instruments were sterile, the operators and the rest of the equipment clean. When the red cells were to be used, 1 cubic centimeter of saturated sodium citrate per 100 cubic centimeters of blood was used as an anticoagulant. When the plasma was saved, heparin[1] was used, 1 milligram for every 2 cubic centimeters of whole blood. The cells and plasma were separated by centrifuging at 2,000 revolutions per minute for 30 minutes. The cells were then suspended in an equal volume of 0.9 per cent saline, re-centrifuged at 2,000 revolutions per minute for 30 minutes, and again suspended in 0.9 per cent saline. This suspension of red cells was used for transfusion. The whole blood was stored in a refrigerator at 4 degrees C. and the cells were washed and suspended immediately before the experiment. When plasma was used, it was separated from the red cells immediately after the bleeding, and stored overnight in a refrigerator at 4 degrees C. It was filtered through gauze once immediately before being used. The dogs were given access to water and food immediately following the operation and during the postoperative period. Every dog that died was examined postmortem, usually within 1 hour after death, but 3 or 4 animals died during the night and no examination was carried out until the following morning.

[1]Hynson, Westcott & Dunning, Lot 156.

TABLE I.—SALINE TRANSFUSION

Dog No.	Wt.	Vol. of blood removed	Amt. of saline perfused	Vol. removed after perfusion	Total protein removed		Preoperative sample		3 hour sample		6 hour sample		24 hour sample		Observations
	kgm.	c.c.	c.c.	c.c.	gm.	gm./kgm.	P.P.	Hemat.	P.P.	Hemat.	P.P.	Hemat.	P.P.	Hemat.	
1	6.4	290	150	250	22.8	3.58	5.50	35.4							Dead—5½ hrs.
2	9.8	440	225	260	29.5	3.02	5.85	38.2							Dead—5 hrs.
3	10.5	530	240	310	39.7	3.70	6.40	33.8	3.32	12.0	3.84	11.7			Dead—18 hrs.
4	10.3	450	240	250	30.9	3.00	5.84	49.6							Dead—40 min.
5	7.6	400	175	200	25.5	3.35	5.20	33.7	3.30	16.8	3.12	16.0	4.05	13.0	Survived
6	7.7	500	177	165	33.4	4.30	6.45	33.0							Dead—2½ hrs.
7	9.8	455	225	300	30.0	3.06	5.69	43.7	2.91	19.0	3.03	18.6	4.44	13.4	Survived
8	11.7	580	270	370	46.7	4.00	6.72	41.7	3.45	16.0					Dead—6 hrs.
9	16.8	1050	386	375	83.6	4.99	7.10	36.6	3.49	13.4					Dead—3 hrs.
10	15.2	1000	350	380	75.1	4.90	6.60	31.6	2.70	12.4					Dead—2 hrs.
11	12.0	575	276	255	46.3	3.90	6.60	46.9	3.90	21.2	4.2	18.8			Dead—9 hrs.
12	9.1	525	210	300	37.1	4.10	5.95	39.4	2.76	18.0	3.48	20.6			Dead—6 hrs.
13	9.4	650	216	245	45.9	4.80	6.20	40.0	3.30	15.9	3.80	18.0	4.80	15.9	Survived
14	10.4	555	240	200	44.3	4.30	6.99	34.0	4.08	16.4					Dead—5½ hrs.
15	5.9	365	136	155	32.5	5.50	7.70	28.4	3.68	10.8					Dead—3 hrs.
Aver.	10.2	558	234	268	41.5	4.03	6.32	37.8	3.35	15.6	3.58	17.3	4.43	14.1	12 died, 3 survived

The total plasma protein removed was measured by determination of the nitrogen in the primary blood removed plus the nitrogen in the postperfusion bleeding. Samples of blood were drawn by jugular puncture at 3, 6, and 24 hours, after operation. In a few instances the final sample was obtained by intracardiac puncture immediately following death. The 0.9 per cent saline was prepared from chemically pure sodium chloride and singly distilled water. It was neither filtered nor autoclaved, nor was it tested or treated for pyrogens. No visible toxic reaction to any of the infused substances was noted. Hematocrit determinations were made in 15 cubic centimeters graduated hematocrit tubes, centrifuged for 30 minutes at 2,000 revolutions per minute. Nitrogen determinations were run on the plasma. The total nitrogen determinations were made by the macro-Kjeldahl method.

EXPERIMENTAL RESULTS

The results of these experiments are summarized in Tables I, II, and III. The washed red cell series was not as long as the others because of the uniform recovery results obtained.

Table I summarizes the results on 15 dogs in which *saline* was given to replace the volume of blood removed before perfusion. This primary bleeding averaged about 5 per cent of the animals' weight or over 50 per cent of the animals' blood volume (4, 8). The blood proteins were reduced from a preoperative average of 6.30 grams per cent to 3.35 grams per cent, 3 hours after operation, while the hematocrits fell from an average of 37.8 per cent to 15.6 per cent over the same period. The 3 dogs that survived for 24 hours had slightly increased their plasma proteins, but their hematocrits were not raised. In the 12 fatal experiments, the average postoperative life of the dogs was 5.5 hours. Very little urine was passed and the dogs, though making an excellent recovery initially, went rapidly downhill and died.

In Table II are the results from the *washed red cell series*. The bleeding in these animals was just as severe as in the saline replacement series, but as can be seen the results were totally different. Recovery on the operating table was most rapid and complete with this series, and the animals did not lose ground afterward. They drank well and ate food when offered, and in general seemed little the worse for the bleeding. The hematocrits were slightly lower after 24 hours than the preop-

TABLE II.—WASHED RED CELL TRANSFUSION

Dog No.	Wt.	Vol. of blood removed	Amt. of saline perfused	Vol. removed after perfusion	Total protein removed		Preoperative sample		3 hour sample		6 hour sample		24 hour sample		Observations
	kgm.	c.c.	c.c.	c.c.	gm.	gm./kgm.	P.P.	Hemat.	P.P.	Hemat.	P.P.	Hemat.	P.P.	Hemat.	
16	6.6	355	152	185	22.0	3.30	5.62	44.7	3.26	48.3	3.25	39.6	3.88	36.0	
17	7.3	350	170	155	20.0	2.73	5.20	40.0	2.32	40.0	3.01	38.6	4.26	26.4	
18	7.7	350	180	250	23.6	3.10	5.77	35.9	4.25	46.0	4.00	42.3			
19	10.6	590	245	350	43.7	4.10	6.74	48.4	3.36	35.8	4.03	37.0	4.88	32.6	All animals survived
20	11.1	500	255	300	38.9	3.50	6.59	45.9	4.03	44.8	4.26	44.4	4.48	35.1	
21	8.4	300	193	300	23.5	2.80	5.82	44.0	3.55	35.1	3.60	31.3	4.60	28.8	
22	8.4	475	193	200	31.5	3.75	5.23	38.9	3.37	46.2	3.23	39.0	3.82	34.0	
23	12.8	800	295	375	58.2	4.50	6.42	48.3	3.71	33.3	3.78	33.5	4.66	27.5	
24	7.5	280	178	210	29.8	3.97	8.60	33.8	3.85	30.5	4.15	32.5	4.56	21.6	
25	7.0	360	160	210	28.7	4.10	5.64	42.5	3.01	57.5	3.21	54.4	4.50	42.1	
Aver.	8.7	436	202	254	32.0	3.59	6.16	42.2	3.47	41.7	3.65	39.3	4.40	31.6	

erative levels, but in 4 cases were higher in the 3 hour postoperative samples. This latter finding probably indicates rapid loss of transfused saline from the circulation. The average plasma proteins were 6.32 grams per cent before operation, and fell to 3.47 grams per cent 3 hours after operation. Subsequent 6 and 24 hour samples showed averages of 3.65 grams per cent and 4.40 grams per cent. The hematocrit readings, on the other hand, showed less change due to the washed red cells in the transfusion fluid. The preoperative hematocrit average was 42.2 and fell slowly to 31.6 over the next 24 hours. Thus the blood proteins were severely depleted, whereas the red cell volume was little affected by the experimental procedure. The slight rise in blood plasma protein probably was due to release of protein from the animals' labile protein reserve stores.

The *heparinized plasma* experiments in Table III were somewhat of a surprise. The first 8 dogs showed 3 deaths and 5 survivals, and it appeared that they had only a 60 per cent chance of survival. Of the next 7 dogs, however, 6 survived. These later dogs were of the same type; there was no change in the technique, and the amount of bleeding was comparable to all the others. The dogs of this series did not seem to recover as quickly as those in either the red cell or saline series while on the operating table. Their postoperative recovery required a longer period of time than that of the dogs which received washed red cells. While the plasma proteins remained within normal range, the hematocrits were reduced 50 to 75 per cent and showed little change during the subsequent 24 hours. The average preoperative plasma proteins were 6.34 grams per cent and in the 11 dogs that survived, showed an average of 6.09 grams per cent 24 hours after operation. The average preoperative hematocrit was 39.1 per cent, and this was reduced to the average of 12.0 per cent 3 hours after operation. After 24 hours it still only averaged 12.4 per cent in the 11 surviving dogs. Hence, these dogs survived despite the marked experimental acute anemia.

Autopsy data are not included in the tables since it may be said that no uniform or characteristic abnormalities were found. Dogs in the saline transfusion and heparinized plasma transfusion experiments showed pallor of the viscera and tissues in all cases. Round and tape worms were occasionally encountered in the intestine. Dog No. 33 had been previously used in some hemoglobin experiments and autopsy revealed a grossly brown pigmented liver. Microscopically, both the parenchymal and Kupffer cells contained many yellow-brown pigment granules. Similar pigment was found in the epithelium of a few kidney tubules. Dog No. 25 showed vegetations on the tricuspid valve with abscesses and infected infarcts of the kidneys. Microscopically, the vegetations showed early organization, and

TABLE III.—HEPARINIZED PLASMA TRANSFUSIONS

Dog No.	Wt.	Vol. of blood removed	Amt. of saline perfused	Vol. removed after perfusion	Total protein removed		Preoperative sample		3 hour sample		6 hour sample		24 hour sample		Observations
	kgm.	c.c.	c.c.	c.c.	gm.	gm./kgm.	P.P.	Hemat.	P.P.	Hemat.	P.P.	Hemat.	P.P.	Hemat.	
26	12.0	580	275	350	44.1	3.67	6.40	43.0	5.22	7.80	5.78	8.2	6.36	11.4	Survived
27	11.3	475	260	250	40.1	3.54	6.50	34.5	6.16	9.40	6.47	10.0	6.67	12.1	Survived
28	8.0	280	184	230	22.4	2.80	5.86	40.2	4.37	13.2*					Dead—2 hrs.
29	13.0	600	300	350	46.9	3.60	6.44	40.0	6.50	6.10*					Dead—1½ hrs.
30	8.6	300	198	210	27.0	3.10	6.22	45.0	5.99	12.8	5.77	12.2	7.00	13.0	Survived
31	10.5	430	240	300	34.4	3.30	5.77	47.1	4.81	17.6	5.14	19.0	5.88	17.4	Survived
32	13.9	660	320	360	42.9	3.10	5.30	49.1	4.97	17.6	5.05	17.6	5.07	14.6	Survived
33	9.3	350	214	200	28.8	3.10	6.31	25.4	4.91	7.50					Dead—2½ hrs.
34	11.6	550	270	375	44.8	3.90	6.57	37.6	5.60	11.9	5.60	10.0	6.30	13.0	Survived
35	9.8	425	225	295	36.2	3.70	6.40	42.4	5.10	12.1	5.40	11.3	6.20	12.2	Survived
36	11.1	625	255	350	48.7	4.40	6.72	40.0	5.66	13.7	5.60	11.5	5.32	10.1	Survived
37	11.7	500	270	350	37.4	3.20	7.30	41.1	6.50	8.50	5.88	10.5	6.57	10.1	Survived
38	6.4	310	146	190	26.9	4.20	6.90	42.9	5.20	16.0	5.05	14.5	5.80	14.3	Survived
39	6.8	375	156	200	26.5	3.90	5.78	32.5	5.28	11.1	5.53	10.8	5.80	11.0	Survived
40	7.6	250	175	240			6.70	25.0	5.73	10.0	5.88	11.2			Dead—9 hrs.
Aver.	10.1	447	232	283	36.2	3.53	6.34	39.1	5.47	12.0	5.59	12.2	6.09	12.4	4 died 11 survived

*Samples taken 1½ hours after bleeding (not included in average).

the abscesses and infarcts appeared to be several days old. We believe that the abnormal findings of these 2 dogs preceded our experiments. No findings of significance related to the shock response were observed in any of the other animals.

OBSERVATIONS

The almost complete failure of the single infusion of saline to maintain the animals beyond a short initial period is a common experience. When both red cells and plasma protein are reduced to the levels indicated in the tables, the animal organism has no resistance to the state of shock, even though its blood volume is replaced immediately by an adequate amount of normal saline. The animal appears to suffer from the anoxia of anemia, and even though mild hemoconcentration and partial replacement of plasma protein occurs, the dog rapidly becomes weaker and dies.

The success of the series in which red cells suspended in saline were used, appears to be due to the immediate replacement of the oxygen carrying capacity of the blood, thereby preventing the occurrence of a severe anoxia. The spectacular recovery of these animals from a condition of shock, fully as profound as that observed in the animals (Tables I and III) that subsequently expired, indicates that the red cell replacement may be of fundamental importance in overcoming hemorrhagic shock. Recovery was the invariable rule when the blood removed was replaced with red cells suspended in saline, whereas replacement with saline alone was accompanied by 80 per cent fatality. Plasma protein levels were equally low in both these series, and plasma protein replacement, therefore, appears less important than red cell replacement.

The poorer results obtained when the volume of the primary bleeding was replaced by heparinized plasma further emphasizes the importance of red cell replacement. The animals of this series were longer in recovering, and 27 per cent died. In the series where the blood was replaced by saline alone, the solution was inadequate to keep the animals alive, even though the hematocrits were often slightly higher than in a successful case in which plasma was used. Blood volume studies were not done, but we feel that there can be little doubt

that plasma replacement is more satisfactory than saline replacement, because, with the former procedure the blood volume is maintained; whereas, with saline replacement the animal must adjust both to anoxia and a shrinking circulatory volume. But the maintenance of the level of the circulating plasma protein at a figure approximating the normal still appears less effective in combatting *shock due to a single severe hemorrhage* than the reestablishment of the red cell volume of the circulation.

SUMMARY

1. A simple, easily duplicated method for producing hemorrhagic shock in dogs is presented. Under local anesthesia, the femoral artery and vein are cannulated. The animal is bled from the artery until the blood flow has practically ceased, and then perfused with 23 cubic centimeters per kilogram of 0.9 per cent sodium chloride solution through the vein to wash out more red cells and plasma. When the bleeding has again practically ceased, the artery is ligated and the volume of test solution equivalent to the first bleeding given immediately into the vein. Following this, the vein is ligated and the wound is closed.

2. In these experiments washed red cells suspended in isotonic saline are found to be more effective than either normal saline alone, or heparinized plasma, in overcoming shock produced by a single severe hemorrhage.

3. Replacement of the oxygen carrying capacity of the blood appears to be more important than the restoration of the normal plasma protein level under the conditions of these experiments.

4. As an emergency measure, isotonic saline is shown to be effective in promoting *temporary recovery* from hemorrhagic shock as produced by a single massive hemorrhage.

REFERENCES

1. Buttle, G. A. H., Kekwick, A., and Schweitzer, A. Lancet, Lond., 1940, 2: 507.
2. Ebert, R. V., Stead, E. A., Jr., Warran, J. V., and Watts, W. E. Am. J. Physiol., 1942, 136: 299.
3. Hoitink, A. W. J. H. Surg. Gyn. Obst., 1935, 61: 613.
4. Ivy, A. C., Greengard, H., Stein, I. F., Grodins, F. S., and Dutton, D. F. Surg. Gyn. Obst., 1943, 76: 85.
5. Muirhead, E. E., Ashworth, C. T., and Hill, J. M. Surgery, 1942, 12: 14.
6. Magladery, J. W., Solandt, D. Y., and Best, C. H. Brit. M. J., 1940, 2: 249.
7. Rossius, L. Arch. klin. Chir., 1925, 137: 583.
8. Smith, H. P., Arnold, H. R., and Whipple, G. H. Am. J. Physiol., 1921, 56: 336.
9. Wiggers, C. J. Physiol. Rev., 1942, 22: 74.
10. Idem. Exp. Med. Surg., 1943, 1: 1.
11. Wiggers, C. J., and Werle, J. M. Proc. Soc. Exp. Biol., N. Y., 1942, 49: 604.

ADMINISTRATION OF ALKALIS IN SULFADIAZINE THERAPY

JOSEPH H. ROHR, M.D., Burlington, Kansas
FREDERICK CHRISTOPHER, M.D., Evanston, Illinois

IT has been shown experimentally and clinically that the renal complications of sulfadiazine therapy can be prevented by the production and maintenance of an alkaline urine (2, 3, 4, 5). Other investigations have shown that an alkaline urine can be maintained by giving from 4 to 19.5 grams of sodium bicarbonate daily.

Bywaters reported in 1942 the use of one-sixth molar sodium r-lactate intravenously for the production of alkaline diuresis. Gilligan and her associates (3) reported in 1943 on 23 surgical patients receiving 5 grams daily of sodium sulfadiazine intravenously. In these 23 cases the incidence of crystalluria was 43 per cent, and all of the specimens of urine which contained crystals were acid. These authors also reported 2 cases in which 1,000 cubic centimeters of one-sixth molar sodium r-lactate was given daily, with alkaline urine and no crystalluria.

Since immediately after operation patients cannot be given oral medication, it was thought desirable to determine a practicable method for rapidly producing alkaline urine for the safe intravenous administration of sodium sulfadiazine and for keeping the urine alkaline up to the time that sodium bicarbonate could be given orally.

In 20 cases following operation the *p*H of 422 specimens of urine was determined, beginning 24 hours prior to and continuing for 5 days after starting alkaline therapy. Each specimen was tested with nitrazine paper[1] within a few minutes after being voided. If the patient had an indwelling catheter, fresh urine from the catheter was tested every 4 to 6 hours. Specimens were examined microscopically at least once daily for sulfadiazine crystals, red blood cells, and casts. Determinations of the carbon dioxide capacity of the blood were made at least once in each case.

Chart 1 shows the *p*H determinations for 65 specimens of urine from 5 patients, ranging in age from 17 to 65 years. These patients had undergone the following operations: appendectomy, 2 cases; transurethral resection of the prostate, 1 case; splenectomy, 1 case; and repair of an inguinal hernia, 1 case. Sodium bicarbonate, 6.0 to 24.0 grams, was given daily in order to determine the time and dosage necessary to establish and maintain urinary alkalinity. It was found that an average of 22 hours was required to establish urinary alkalinity. Daily administration of 24.0 grams of sodium bicarbonate[2] in 4 divided doses in water was the lowest dosage which would keep the urine alkaline. The highest carbon dioxide capacity was 71 volumes per cent after 8 days of administration of 24 grams of sodium bicarbonate daily, and the lowest was 49 volumes per cent on the first day of alkali therapy. Therefore, if the surgeon wishes to use sulfadiazine therapy without danger of renal complications he must wait the number of hours necessary for tolerance of oral administration of sodium bicarbonate plus 22 or more hours for the establishment of urinary alkalinity.

Chart 2 shows the *p*H determinations for 145 specimens of urine from 7 patients, ranging in age from 29 to 70 years. These patients had undergone the following operations: appendectomy, 2 cases—in 1 case the appendicitis was acute, with gangrene and localized peritonitis and, in the other there was acute appendicitis with abscess; nephrectomy, 1 case; repair of an inguinal hernia, 1 case; cholecystectomy, 2 cases; and cystotomy for Escherichia coli peritonitis from urinary extravasa-

From the Department of Surgery, Evanston Hospital, Evanston, Illinois.

[1]Nitrazine paper (sodium dinitrophenol-azo-naphthol disulfonate), E. R. Squibb & Sons.

[2]When 1 level teaspoonful of sodium bicarbonate is given 4 times a day, approximately 24 grams is the total dosage.

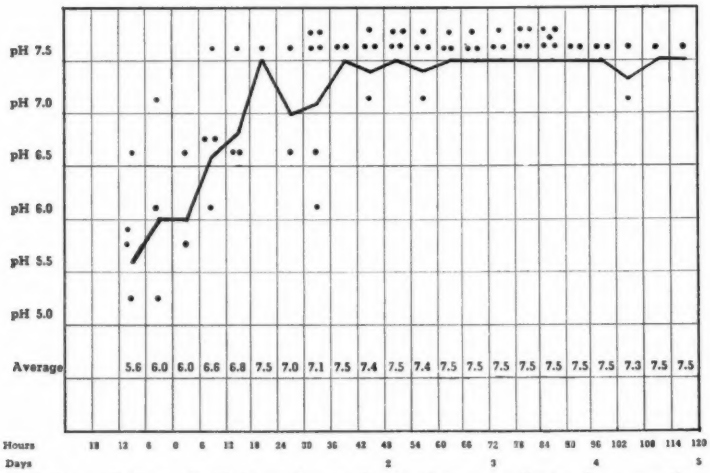


Chart 1. Urinary *p*H of 65 specimens of urine from 5 patients after operation. Zero hour indicates the beginning of oral administration of sodium bicarbonate.

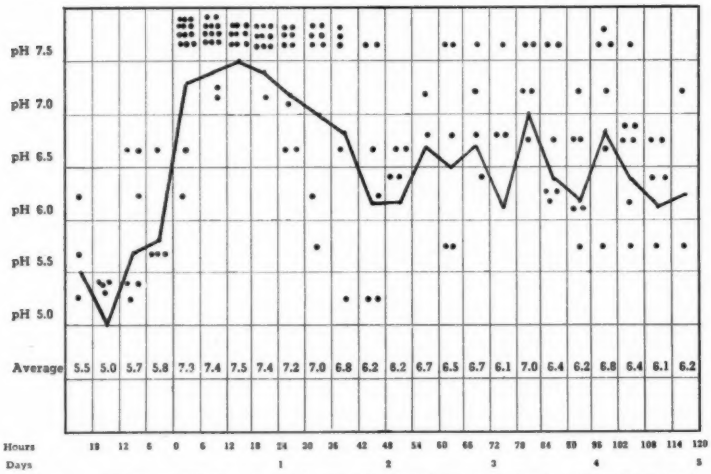


Chart 2. Urinary *p*H of 145 specimens of urine from 7 patients. Zero hour indicates completed intravenous administration of 1,000 cubic centimeters of one-sixth molar sodium r-lactate.

tion, 1 case. On the first postoperative day each patient received 1,000 cubic centimeters of one-sixth molar sodium r-lactate[1] intravenously; 2 patients received it for 2 days; 1 for 3 days, and 1 for 4 days. The last mentioned patient was given a total of 5,500 cubic centimeters of one-sixth molar sodium r-lactate intravenously. The urine was alkaline in the majority of cases by the time the intravenous injection was finished, and in all cases it was alkaline 3 hours afterward, remaining so for an average period of 24 hours. The highest carbon dioxide capacity was 76 volumes per cent after 4,500 cubic centimeters of one-sixth molar sodium r-lactate had been given over a period of 4 days. The lowest was 47 volumes

[1]Each 100 cubic centimeters of one-sixth molar sodium r-lactate contains 1.866 grams of sodium r-lactate.

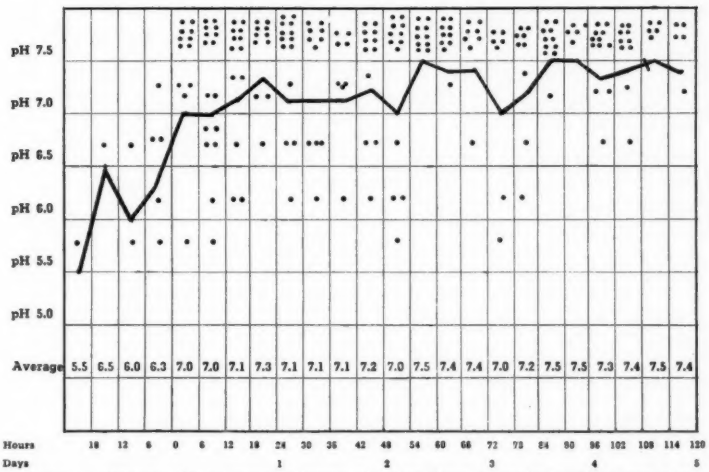


Chart 3. Urinary *p*H of 212 specimens of urine from 8 patients who were given 1,000 cubic centimeters of one-sixth molar sodium r-lactate intravenously daily after operation, followed by sodium bicarbonate orally when tolerated. Zero hour indicates completion of intravenous administration of 1,000 cubic centimeters of one-sixth molar sodium r-lactate.

per cent and was recorded on the 4th day for the patient receiving 3,000 cubic centimeters. One patient received 40 grams of sodium sulfadiazine intravenously over a 6 day period. Daily for 6 days 1,000 cubic centimeters of one-sixth molar sodium r-lactate was given, and no crystals in the urine or other renal complications developed. Another patient received 2.5 grams of sodium sulfadiazine intravenously without renal complications or crystalluria.

Chart 3 shows the *p*H determinations for 212 specimens of urine from 8 patients, after operation, who were given one-sixth molar sodium r-lactate intravenously followed by sodium bicarbonate orally as soon as tolerated. Their ages ranged from 4 to 71 years. These patients had undergone the following operations: appendectomy, 5 cases—in 2 cases there was acute appendicitis with perforation and Escherichia coli peritonitis, in 1 case acute appendicitis with perforation and localized peritonitis, in 1 case acute appendicitis with gangrene, and in 1 case acute appendicitis with abscess, repair of an inguinal hernia, repair of an incisional hernia, and cholecystectomy. This chart shows, as did Chart 2, that by the intravenous administration of 1000 cubic centimeters of one-sixth molar sodium r-lactate urinary alkalinity was promptly established, and by the administration orally of sodium bicarbonate the alkalinity was maintained. The carbon dioxide capacity ranged from 40 to 75 volumes per cent. The dosage of sodium bicarbonate was from 3 to 30 grams daily. Again, 24 grams of sodium bicarbonate in 4 divided doses was the smallest amount that would consistently keep the urine alkaline. Six patients were given a total 5 day dosage of 5.0 to 31.5 grams of sulfadiazine orally and sodium sulfadiazine intravenously. A few red blood cells were observed microscopically in 3 specimens of urine in this group. There were no sulfadiazine crystals.

A 4 year old patient with severe Escherichia coli peritonitis was given 1000 cubic centimeters of one-sixth molar sodium r-lactate intravenously daily for 2 days, with 1.75 grams of sodium sulfadiazine intravenously daily for 2 days followed by sulfadiazine and 6.0 grams of sodium bicarbonate orally daily. In this case the highest carbon dioxide capacity was 60 volumes per cent and the lowest 53 volumes per cent. There were no sulfadiazine crystals present.

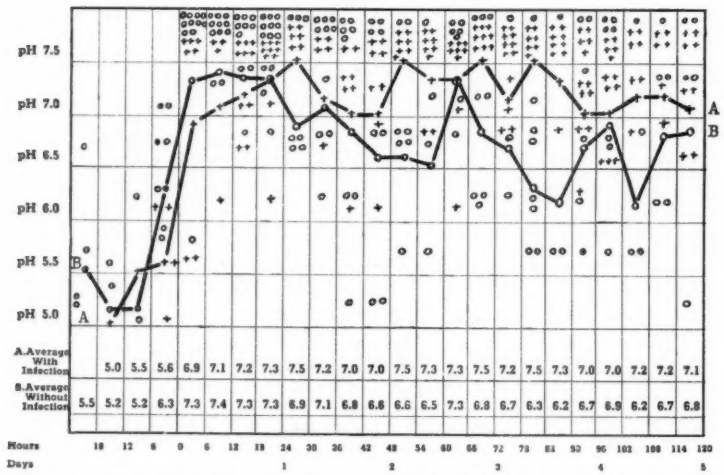


Chart 4. Urinary *p*H determination for patients with infection (*A*+) compared with the *p*H determinations for those without infection (*Bo*). Zero hour indicates completion of intravenous administration of 1,000 cubic centimeters of one-sixth molar sodium r-lactate.

One patient who did not receive sodium r-lactate after operation had had sulfathiazole placed in the abdomen at operation, and 2 days later oliguria, abdominal pain, hematuria, and heavy sulfathiazole crystalluria developed, all of which promptly disappeared after administration of 1,000 cubic centimeters of one-sixth molar sodium r-lactate intravenously and 30 grams of sodium bicarbonate by mouth for 2 days.

Sodium sulfadiazine precipitates with one-sixth molar sodium r-lactate when mixed in the flask or in the intravenous tubing. Therefore, our method was to add 500 cubic centimeters of normal saline solution to the intravenous set when the one-sixth molar sodium r-lactate had been given and after 200 cubic centimeters of normal saline solution had been given to add sodium sulfadiazine to the remaining 300 cubic centimeters of saline solution. Ampuls containing 10 cubic centimeters of 25 per cent solution of sodium sulfadiazine were used. If additional glucose and fluids were desired, 5 or 10 per cent dextrose in lactate-Ringer's solution[1] was given, and if several days of intravenous administration of fluids was anticipated, 1,000 cubic centimeters of amigen[2] daily was often given intravenously to supply protein.

Chart 4 shows the *p*H determinations for 7 patients after operation with moderate to severe infection compared with those for 8 patients with minimal or no infection. Clinically, the patients with infection required more alkali to produce and maintain alkalinity of the urine.

Schmelkes has reported that the *p*H of infected wounds is between 5 and 6 while that of clean wounds is 7.3. He has also shown that measured against certain organisms, one-tenth as much sulfathiazole will overcome 1 mol of the sulfonamide inhibitor para-aminobenzoic acid at *p*H 7.5 as at *p*H 5.0. Clinically we have observed that surgical patients with severe infection have recovered very rapidly with sulfadiazine and alkali therapy.

SUMMARY AND CONCLUSIONS

1. The *p*H determinations for 422 specimens of urine from 20 patients after operation were analyzed.

2. One-sixth molar sodium r-lactate intravenously was shown to be efficient for the rapid production of urinary alkalinity

[1]Lactate-Ringer's solution contains in each 100 cubic centimeter 0.6 gram sodium chloride, 0.31 gram sodium r-lactate, 0.03 gram potassium chloride and 0.02 gram calcium chloride.

[2]Five per cent solution of amigen, of dextrose: a sterile aqueous solution of an enzymic hydrolysate of purified casein and pancreas with 5 per cent solution of dextrose, adjusted to *p*H 6.5, Mead Johnson & Co.

3. It was found that 1,000 cubic centimeters of one-sixth molar sodium r-lactate maintained urinary alkalinity for an average of 24 hours.

4. At least 24 grams per day of sodium bicarbonate was necessary to maintain urinary alkalinity after the intravenous administration of fluids was discontinued.

5. Renal complications were not found after sulfadiazine administration when the urine was rendered alkaline.

6. Sodium sulfadiazine should not be mixed with or come in contact with one-sixth molar sodium r-lactate in the intravenous set.

REFERENCES

1. Bywaters, E. G. L. Brit. M. J., 1942, 2: 646.
2. Fox, C. L., Jensen, O. J., and Mudge, G. N. J. Am. M. Ass., 1943, 121: 1147.
3. Gilligan, D. R., Garb, S., and Plummer, N. Proc. Soc. Exp. Biol., N. Y., 1943, 52: 248.
4. Gilligan, D. R., Garb, S., Wheeler, C., and Plummer, N. J. Am. M. Ass., 1943, 122: 1160.
5. Jensen, O. J., Jr., and Fox, C. L., Jr. J. Urol., 1943, 49: 334.

A CLINICAL SYNDROME ASSOCIATED WITH A RARE ANOMALY OF THE VENA PORTAE SYSTEM

JOHN FRASER, M.D., F.R.C.S. (Ed.), F.A.C.S., and A. KINGSLEY BROWN, M.B., Ch.B.,
Edinburgh, Scotland

ANOMALIES of the portal vein are rare. Instances have been recorded in which the portal stream has been conveyed to the liver in twin channels; such findings are of interest to the anatomist, but on no occasion has it been recorded that the anomaly has been associated with symptoms or physical signs indicative of a disease syndrome. Recently a case came under observation presenting what must be a very uncommon disposition of the venous channels of the portal system, and, as the anatomical findings were associated with a distinctive clinical picture, the occurrence may be thought worthy of record.

Mrs. A. W., aged 31 years, quadripara, was admitted to the Edinburgh Royal Infirmary on account of jaundice associated with increasing general debility. She stated that, subsequent to the birth of her last child 11 months before, she experienced a progressive deterioration in body strength and vitality. Associated with these general features there was a feeling of distention and heaviness in the abdomen, particularly after meals, and from time to time vomiting occurred: this afforded temporary relief from the feeling of distention. There were frequent and copious stools, and the patient noted that the bowel matter was consistently pale and, indeed, often clay-colored. Sometimes there were attacks of diarrhea, considerable in amount and creamlike in appearance. Loss of weight became noticeable and with it a decline in strength and energy; the appetite deteriorated, anorexia developed combined with a pronounced distaste for any food of a fatty nature. Four weeks before the patient's admission to hospital jaundice appeared. At first it was slight and evanescent: latterly it became persistent and more intense. The menses, hitherto regular in incidence and normal in amount, diminished in quantity, and for 3 months before admission to hospital there was complete amenorrhea.

The patient was a slightly built and somewhat ill nourished woman. There was general icterus of a moderate degree: she appeared depressed and exhausted, and it was evident that a serious degree of illness existed. On the other hand, the temperature and pulse rate were normal, the tongue was clean and moist.

The respiratory and cardiovascular systems showed no evidence of disease. A blood examination gave the following findings: red blood cells, 4,930,000; hemoglobin, 95 per cent; color index, 1; white blood cells, 2,400. The red corpuscles showed marked anisocytosis, hypochromic and hyperchromic cells being in about equal proportions; the platelet count was normal and a differential white cell count gave approximately average readings.

The urine reaction was acid; albumin, sugar, and acetone were absent, but bile was present in considerable amount. The nervous system was healthy, and the Wassermann reaction was negative.

The main interest centered around the examination of the alimentary system. Considering the degree of general malnutrition, the abdomen was unduly protuberant, and investigation showed that this was the result of intestinal distention. It was thought that a small amount of free fluid was present, but this observation was uncertain. There was some tenderness accompanied by muscle rigidity in the upper right quadrant of the abdomen; the lower border of the liver could be palpated immediately beneath the right costal margin, its outline was smooth and uniform; the gall bladder did not appear to be distended. There was an appreciable degree of splenomegaly, the anterior border and lower pole of the organ could be palpated at a distance of 4 inches below the left costal margin, the outline was smooth and uniform, and the notch easily perceptible. The rectal examination was negative.

A straight x-ray examination showed a considerable degree of gas distention of small and large intestines: it confirmed the clinical observation that a splenomegaly existed: it revealed no evidence of calculus formation in any part of the biliary tract.

A barium meal and barium enema examination were carried out with negative results. In view of the existence of jaundice it was thought inadvisable to attempt an opacol (S.T.I.P.P.) investigation.

Special investigations. The blood urea nitrogen was 13 milligrams per cent (Van Slyke). The icteric index, estimated by the Meulengracht method, was 67. The van den Bergh test was reported as showing a direct biphasic reaction. Examination of the stool showed an increased proportion of unsplit fat. The readings were as follows: total fat, 62; split fat, 35; unsplit fat, 65. It was noted that the feces contained a number of fat globules; these were particularly evident when diarrhea occurred, and it was obvious that their presence explained the creamy appearance of the stool at this time. Analysis of the gastric juice gave the following readings: total acidity, 12; free acidity.

The preoperative diagnosis. The patient was admitted to hospital on a provisional diagnosis of pancreatic disease, either a neoplasm of the body of the pancreas, which was beginning to involve the head of the organ, or a chronic pancreatitis. This diagnosis was based upon various features in the clinical history—the increasing general debility accompanied by loss of weight, the gastric disturbance indicated by loss of appetite, flatulence, and vomiting, the diarrhea, the character of the stools: in the later stages of the illness the development of an obstructive jaundice appeared to lend confirmation to the view that pancreatic disease existed.

The clinical investigation while not confirmatory appeared to support this diagnosis, but one confusing element was the splenomegaly. The explanation and significance of this feature were obscure, and it was difficult to visualize the part which it played in the clinical picture.

None the less while recognizing that there were inconsistencies, the bulk of the evidence supported the diagnosis of pancreatic disease, probably malignant in character: it was decided therefore that the situation justified exploration by operation. It was considered that this afforded the only

means by which an accurate diagnosis could be arrived at, and it was thought that, if the position could be clarified, a way might be found of affording at least a temporary relief of symptoms.

Prior to operation certain preliminaries were carried through: the prothrombin element of the blood was reinforced by the administration of vitamin K (intramuscular injections of kapilon 1 c.c. 4 hourly over a period of 48 hours), while, in view of the leucopenia, a small transfusion of blood (500 c.c.) was given 12 hours before operation.

Findings at operation. The abdominal cavity was entered through a right upper paramedian incision. The peritoneal space contained a quantity of fluid which was faintly bile-stained; though appreciable in amount, it was not excessive.

On proceeding to examine the viscera interest was focused on the appearance presented in the subhepatic region. Beneath the peritoneum in relation to the right gastropancreatic fold of peritoneum and the lesser omentum and along the line of the hepatic and common bile ducts, there were a number of bluish, fluid-containing saccules. On first impressions the condition appeared to be one of multiple cysts of the bile ducts, but, when the peritoneum was divided and stripped off, it was seen that the saccules were venous in origin and that the state was one of a tortuous multiform varix showing cystlike dilatations at many points. Further dissection established the identity and relationships of the plexus: caudally it was in communication with the superior mesenteric vein, the right half of the splenic vein shared in the varicosity, and there seemed to be no doubt that the venous stream from the spleen communicated with the varix. In its relationships and associations, therefore, it appeared to correspond to the distribution of the portal venous stream (Fig. 1). An attempt was made to ascertain whether a portal vein existed in the normal situation, but the varicosity made the dissection difficult and indeed dangerous. The ultimate exposure was not satisfactory, but it was established that a portal vein of small size lay in its normal relation on the posteromedial aspect of the common bile duct.

A review of the abdominal viscera brought out some interesting facts. The liver was normal in size and appearance; the gall bladder was smaller than usual, its wall was thickened and edematous and the distribution of the cystic vein showed a miniature varicosity; there were no gallstones. The tubulobiliary system was healthy, and, so far as could be ascertained, there was no abnormality of the arterial distribution. The appearances and consistency of the pancreas suggested that it was the site of a mild degree of diffuse chronic pancreatitis. The spleen was enlarged to twice the usual size, its surface was smooth and uniform, its consistency firm; in general its appearance suggested that it was the site of a chronic venous congestion with secondary fibrotic changes.

No gross structural changes were apparent in the stomach or in the segments of the small and large bowels which could be brought under review, but these organs presented a congested appearance, while here and there patches of subperitoneal edema were apparent. The impression given was that there was a considerable degree of venous engorgement throughout the area drained by the portal stream.

Reviewing the situation in the light of the operation findings, it appeared that the condition presented in the subhepatic region was a true varix of an abnormal portal vein distribution. The anatomical interest of the anomaly and the explanation of the part which it played in the clinical picture are discussed in the commentary; the immediate problem of the moment was to decide upon the means by which the situation could be relieved. It seemed that only one course was possible—to ligature and if possible to eradicate the dilated and abnormal channels, trusting that the sequel would be to divert the portal venous return into the small, but otherwise normal, vessel. It was assumed that the concentration of the flow into a single channel would be followed by a degree of dilatation adequate to accommodate the increased bulk of blood. The plan was put into operation. It proved difficult, for the dilated venous radicles were extremely thin walled, many of them ruptured when an attempt was made to separate them, and, indeed, the degree of hemorrhage was disconcerting. In order to secure adequate access to the higher portion of the varix it was necessary to remove the gall bladder, but even so the difficulties in the immediate subhepatic region were so great that gauze packing

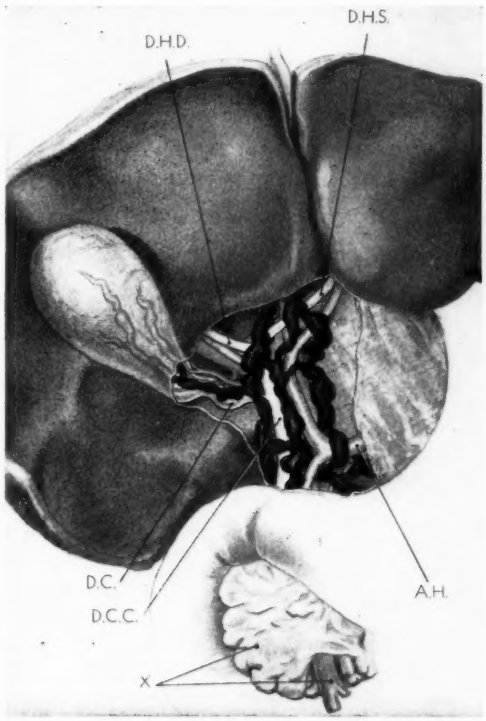


Fig. 1. The appearances of the portal varix as revealed at operation: *D.H.D.*, Right hepatic duct; *D.H.S.*, left hepatic duct; *D.C.*, cystic duct; *D.C.C.*, common bile duct; *X*, part of pancreas and superior mesenteric vein.

had to be resorted to before the bleeding could be controlled. Eventually hemostasis was satisfactory and complete, and, after drainage was established by means of a strip of dental rubber, the abdominal wound was closed.

Postoperative progress. The patient's progress after operation was uneventful and satisfactory. The jaundice diminished and by the end of the third week all trace of pigmentation had disappeared. An icteric index estimation during the fourth week yielded a normal reading (4). An interesting response was recorded in the blood picture: the preoperative leucopenia (2,400) was replaced by a leucocytosis, the blood readings one week after operation being: red blood cells, 5,630,000; hemoglobin, 102 per cent; white blood cells, 23,000. Equally satisfactory was the improvement in the general condition. The appetite returned, the stools became normal in occurrence and in appearance, all sense of abdominal discomfort and distention disappeared, and the weight increased. The patient was discharged from hospital in good health 5 weeks after operation, and since that date, now 8 months ago, her progress has been satisfactory.

It seemed beyond doubt or question that the varicose venous channels lying in relation to the right gastropancreatic fold of peritoneum and to the lesser omentum represented an abnormal and accessory distribution of the portal vein. Their identity was established on several grounds: their beginnings could be traced in continuity with the splenic and superior mesenteric veins, their ultimate distribution was into the *porta hepatis*, they occupied an area in which the portal channel is the sole venous representative. It is true that their anatomical relations to the bile duct and the hepatic artery were abnormal: several of the channels were superficial to these structures, others intertwined around and among them, but the relation of a varix to adjacent tissues is invariably indefinite, and in this instance a disturbance of the usual relations was a natural consequence of the abnormality.

Having identified the anatomy of the varix, it was natural to enquire about its origin. One thing seemed to be clear—it represented a developmental abnormality, in all probability a persistence of certain portions of the embryonic and fetal venous dispositions from which the portal vein arises. Doubtless the stress and strain of postnatal life had played a part in creating the varicosities, but it was surely an inescapable conclusion that the origin of the condition could be traced to the persistence of fetal portal radicles.

The portal vein arises from certain modifications and adjustments of the right and left vitelline veins, the channels which at an early stage of development convey blood from the yolk sac portion of the entodermal vesicle to the primitive ventral aortae, and at a later stage of development to the sinus venosus of the primitive heart. With the delimitation of the duodenum the vitelline veins come to lie to the right and left of this portion of the foregut. In this situation they are united by three transverse channels, two of which lie ventral and one dorsal to the gut, so that the arrangement resembles a venous ladder extending along the duodenum and in the caudal direction passing into the substance of the developing liver, where they form the channels of the sinusoidal system. As development proceeds, certain segments of the vitelline venous ladder degenerate and disappear, but three portions remain—the cephalic end of the left limb of the caudal loop between the vitelline veins, the dorsal intervitelline channel, and the right limb of the cranialward loop. It is from a continuity of these three elements that the portal vein arises, and the linkage with the visceral field is completed almost simultaneously when the superior mesenteric and splenic veins establish communication with the left vitelline vein at a point immediately caudal to the dorsal transverse anastomosis (Fig. 2).

Such being the normal arrangement, how is the anomaly under discussion to be explained? Various possibilities present themselves: (1) the persistence of the right vitelline vein as an independent channel; (2) the existence of a double right vitelline vein, one branch entering into the formation of the *vena portae* while the other retained its independence; (3) the persistence of the caudal segment of the right vitelline vein. The relations and disposition of the varix were not in keeping with the third explanation, for in this event one would have expected that the cephalic end would have opened into the main portal vein. The fact that it passed into the liver through the porta hepatis suggested that it represented either the right vitelline vein *in toto* or an independent radicle of an abnormal twin structure. No doubt in their beginnings the abnormal radicles were but slender and miniature structures; as growth proceeded they underwent enlargement, and it is probable that for a time they provided channels of conveyance which functioned relatively normally. Then came the stage of varicosity and saccule formation, and it may be presumed that these reactions were dependent upon a variety of influences. The wall of the portal vein presents peculiar features. The main constituent is areolar tissue, the muscle is not arranged as a continuous sheet, but as a series of bands separated by strands of fibroareolar tissue. It is probable that in abnormal radicles of the portal series these peculiarities of structure are exaggerated, and, if so, the liability to dilatation was likely to be increased. It

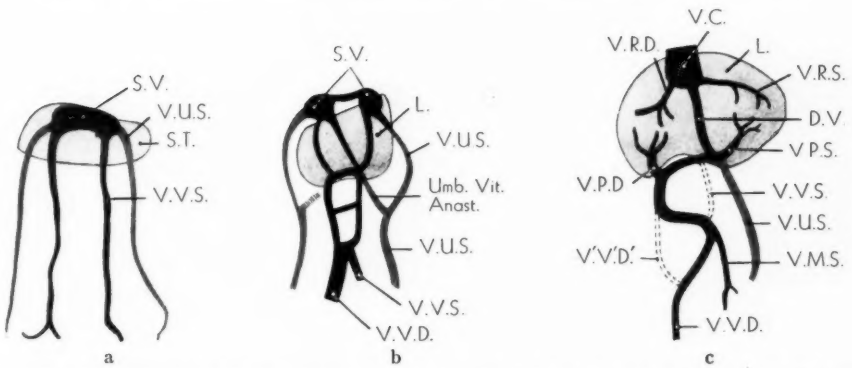


Fig. 2. The development of the portal system. The probability is that the anomaly recorded represents either persistence of portions of the right vitelline vein or of independent radicles of an abnormal twin structure.

a, *S.V.*, Sinus venosus; *V.U.S.*, left umbilical vein; *S.T.*, septum transversum; *V.V.S.*, left vitelline vein.

b, *S.V.*, Sinus venosus; *L.*, liver; *V.U.S.*, left umbilical vein; *Umb.Vit.Anast.*; *V.U.S.*, left umbilical vein; *V.V.S.*, left vitelline vein; *V.V.D.*, right vitelline vein.

c, *V.C.*, Upper or cephalic part of inferior vena cava; *V.R.D.*, right vena revehens; *L.*, liver; *V.R.S.*, left vena revehens; *D.V.*, ductus venosus; *V.P.S.*, left branch of portal vein; *V.V.S.*, atrophied part of left vitelline vein; *V.U.S.*, left umbilical vein; *V.M.S.*, superior mesenteric vein; *V.V.D.*, right vitelline vein; *V'.V'.D'.*, atrophied part of right vitelline vein; *V.P.D.*, right branch of portal vein. (Reproduced by permission from Cunningham's *Textbook of Anatomy*.)

may be argued too that the mode of distribution of the portal vessels encourages a tendency to varicosity if structural weakness of the wall exists: they terminate, as arteries do, in a capillary system, an arrangement which is likely to raise the pressure within the afferent channels. It is probable that these influences played a predisposing part, and it may be that they initiated the early stages of varicosity, but it seems evident from the clinical history that an additional element came into play, the result of which was to lead to a rapid and exaggerated development of the varix; it is suggested that this precipitating factor was the succession of four pregnancies within a period of 5 years. No doubt the effect of these developments was to increase the strain upon the portal circulation, and it may be assumed that the consequences led to exaggerated varicose changes in the weak and abnormal segments of the portal channels. On a basis such as this it is possible to visualize a state of affairs which initiated the error and led ultimately to a gross degree of varicosity.

From the clinical standpoint there is special interest in visualizing the part which the varicose anomaly played in the case history and physical findings. It seems that there can be but one explanation—that the varix was responsible for a progressive and, indeed, an acute degree of portal stasis. In some respects the clinical picture bore a resemblance to that encountered in cirrhosis of the liver—the loss of weight and impairment of strength, the increase of peritoneal fluid, the splenic enlargement, the gastritis and enteritis, the recurrent jaundice; all of these were present, and, if the liver had shown fibrotic changes, the picture would have been reasonably complete, but in this instance the liver was healthy, and it was evident that the obstructing element was the abnormal and varicose portal vein distribution.

The manner in which it exerted its effect must be a matter of conjecture, but it seems reasonable to advance the argument that the condition offered a parallel to that which exists in varicosity of the superficial veins of the lower extremity. It is agreed that in the latter instance the varix presents a definite hindrance to an efficient venous circulation, the blood flow within it is apt to be static and inert, and, while the relative increase in the capacity provided is likely to attract blood from contiguous and related channels, the ultimate result is to create a catchment area in which blood tends to stagnate, a state of affairs which prejudices the efficiency of the related circulation and vitiates the health of the tissues from which the blood intake is derived.

As we see it, that is the situation which arose in the case under discussion. It meant that a progressive and relatively acute degree of portal stasis came to be established, obstruction of the venous return from the spleen led to the splenomegaly, venous congestion of the stomach and duodenum accounted for the vomiting, the gastric distention, and the various dyspeptic symp-

toms; a similar development in the area of the pancreas disturbed the physiological activity of that organ with consequent derangement of the digestion of fats and starches. Secondary to the congestion and edema of the head of the pancreas a catarrhal cholangitis developed the feature which explained the jaundice; parallel changes in the small intestine appear to have interfered with fat absorption by the lacteals, so that a form of steatorrhea resulted—indeed the entire clinical picture, subjective and objective, can be interpreted in terms of a relatively acute portal obstruction.

One consideration remains for discussion: it may be put in the form of a question. Why should the obliteration of the varix result in the disappearance of symptoms? That it has done so permanently indicates that it led to a relief of the state of portal congestion, but the pertinent question is how this was achieved. It may be that the answer is provided in the parallel already alluded to—varicosity of the superficial veins of the lower extremity. It is clear that in this affection obliteration of the dilated superficial channels leads to an improvement in the circulatory condition of the limb. It does so by returning into active circulation a volume of blood which otherwise would remain in a condition of physical and physiological inertia, and by so doing it benefits tissue nutrition and the tone and pressure of the circulation. This explanation and reasoning are surely equally applicable to the condition under discussion; indeed, it would be difficult to suggest any other solution, and therefore we assume that the obliteration of the varix resulted in the re-establishment of a healthier portal circulation and the restoration of the physiological balance of the tissues in the portal field.

SUMMARY

An account is given of the case history and clinical findings associated with a rare anomaly of the development of the vena portae—varicose changes in the abnormal vessels resulted in a state of subacute obstruction in the portal circulation with the presentation of a consequent disease syndrome: obliteration of the varix was followed by relief of the obstruction and the disappearance of the clinical syndrome.

HEALING OF THE ABDOMINAL WALL AFTER LOOP COLOSTOMY

An Experimental Study

ALEXANDER SLIVE, M.D., M.Sc. (Med.), DAVID SHOCH, Ph.D., and SAMUEL J FOGELSON, M.D., F.A.C.S., Chicago, Illinois

IN order to avoid such complications as peritonitis, cellulitis of the abdominal wall, and evisceration, surgeons endeavor to defer the opening of a loop colostomy until they believe that healing between the bowel and abdominal wall is complete enough to prevent these sequelae. When intestinal obstruction is absent, there is no urgency about opening the loop of bowel, and the problem is obviated. In complete, acute obstructions, however, the desirability for the earliest possible drainage must be balanced against the chance that contaminating organisms might cause an infection of the peritoneal cavity or abdominal wall. Surgical opinion varies as to the safest time for opening a loop colostomy. Rankin and Graham state: "After 48 hours, the natural reparative powers of the tissues seal off the peritoneal cavity and it is safe to open the bowel. This, however, is best postponed for 6 or 7 days."

The object of this experiment was to evaluate quantitatively at various times after operation the strength of union between the colon loop and abdominal wall in animals with loop colostomies.

METHODS

The following operation was performed on 48 dogs. A loop of colon was delivered through a right transrectus incision 4.5 centimeters long and placed halfway between the pubis and xiphoid process. The afferent and efferent limbs of the exteriorized loop were united with four interrupted silk seromuscular sutures placed 1 centimeter apart. This procedure was employed to prevent other segments of intestine from entering the space between the two limbs of the colostomy loop, and also because this technique is a frequent clinical practice when spur formation and a temporary colostomy is desired. The peritoneum and the anterior rectus sheath were each united with four interrupted chromic 20 day No. 000 sutures, two above and two below the colon loop. The skin edges were closed in the same manner, four silk sutures being used. As no sutures were used between the bowel and abdominal wall, retraction of the loop into the peritoneal cavity was prevented by perforating the mesocolon with a piece of rubber tubing placed external to the skin.

The strength of the healing process between the colon loop and abdominal wall was determined by inserting a 14-gauge needle through the abdominal wall into the peritoneal cavity on the side opposite the colostomy. The needle was connected by a rubber tubing to a bicycle pump through a large mercury manometer. Then, with the dog's trunk held under water, the peritoneal cavity was inflated and the pressure noted at the moment air bubbles appeared, indicating leakage between the abdominal wall and the colostomy loop.

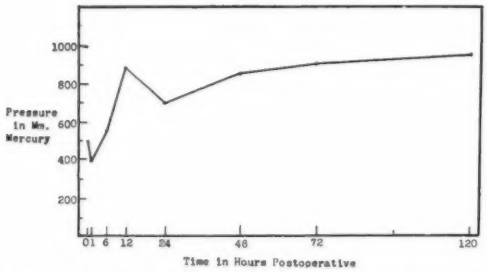
The nearness of the peritoneal and fascial sutures to the bowel loop varied slightly with the size of the bowel, in order to secure a snug closure around the loop. The same surgeon performed all the operations, and it was endeavored to secure a reasonably similar mechanical tension around the exteriorized loop of colon throughout the experiment. A relatively large series of animals was used to diminish the element of chance. In comparing averages of biologic series, individual variations within a series may be so large as to cancel any significance. Therefore, Fisher's mathematical formulas and tables (pages 128 and 177), were used to determine the percentage of error in each series or group, and calculate whether the results of comparisons were very significant, slightly significant, or not significant.

The 48 dogs were divided into 8 groups of 6 each. Pressure determinations were made on the first group immediately after operation, and on the remaining groups after 1 hour, 6 hours, 12 hours, 24 hours, 48 hours, 3 days, and 5 days.

RESULTS

Although the procedure used in this experimental study does not reveal any objective information as to the histopathology or bacteriology of the healing process between the bowel and abdominal wall, it does indicate the strength of this

From the Division of Surgery, Northwestern University Medical School.



Graph 1. Average pressure required to force air between abdominal wall and colostomy loop.

union. Since the tensile strength of inflammatory tissue undoubtedly depends on the fibroblastic elements present, it seems logical to assume a directly proportional relationship between the tensile strength of such a tissue and its rôle as a barrier to the spread of infection. The table shows the average pressure required to force air between the abdominal wall and colostomy loop in each postoperative group. These figures are shown in graph form to facilitate interpretation. After the percentage of error in each group is determined and the significance of comparisons calculated according to Fisher's method, it is found that the colostomy wound after 1 hour is slightly weaker than immediately after operation. Between 1 hour and 12 hours, there occurs a progressive and rapid increase in strength. At 24 hours after operation there is a slightly significant drop in strength as compared with the 12 hour determination. There is no significant difference in strength between the determinations taken at 12 hours, 48 hours, 3 days, and 5 days. These results are interpreted as indicating that it is safest to wait at least 12 hours before a loop colostomy is opened, preferably 48 hours.

TABLE I.—PRESSURE REQUIRED TO RUPTURE COLOSTOMY SITE

Time in hrs. after operation	Pressure mm. Hg.	Time in hrs. after operation	Pressure mm. Hg.
0	490*	24	704
1	390	48	845
6	555	72	908
12	875	120	950

*Each number is average of determinations on 6 dogs.

CONCLUSIONS

1. The strength of a loop colostomy wound is at its weakest point 1 hour after operation.
2. The greatest and most significant increase in the strength of the healing process between a loop colostomy and the abdominal wall occurs between 1 and 12 hours after operation.
3. Between 12 and 24 hours there is a slightly significant drop in strength which is recovered by the 48th hour and is not significantly changed up to and including the 5th day after operation.

REFERENCES

1. Fisher, R. A. Statistical Methods for Research Workers. Edinburgh: Oliver and Boyd, Ltd., 1938.
2. Rankin, F. W., and Graham, A. S. Cancer of the Colon and Rectum. Springfield, Illinois: Chas. C. Thomas, 1939.

INERT METALS IN DIRECT FIXATION OF MANDIBULAR FRACTURES

ALVIN E. STROCK, D.M.D., Boston, Massachusetts

CIRCUMFERENTIAL wiring, skeletal fixation, and direct wiring of fractures of the mandible are accepted surgical procedures in the absence of teeth in which cases displacement precludes the use of indirect fixation by splinting.

Circumferential wiring has been found unsatisfactory by us and others (3, 4, 13) for accurate reduction of displaced fragments.

Skeletal fixation necessitates compounding a fracture extraorally with its attending danger of secondary infection. Pins may become loose due to local necrosis as the result of the use of poor technique, such as overheating while burring pin holes (8), by accident during sleep (11), or from injury to the membrane which lines the pin or screw tracts (10, 12). Skeletal fixation does not permit removal of fibrous tissue between fractured fragments in cases of delayed treatment without open operation in addition to extraoral fixation (3). Used in the presence of teeth skeletal fixation carries the danger of causing devitalization (8), and faulty occlusion (9). It requires special, expensive apparatus (Fig. 1,a). If successfully applied it is unsightly (Fig. 1,b), requires removal, discourages transfer of patient from one point to another because of the necessity for this removal and because of the value of the appliances. Finally, skeletal fixation may result in undesirable scarring or dimpling of the skin of the face (3). If successfully applied its desirable features are control of fragments and allowance for normal function of the parts.

Dr. Strock, Acting Dental Surgeon, Peter Bent Brigham Hospital.

From the Dental Service of the Peter Bent Brigham Hospital and the Harvard Medical School Laboratory of Surgical Research.

If fragments are accessible, intraoral direct wiring is the simplest method of fixation (5). This technique requires merely a small amount of readily available wire, the cost of which is negligible. It is well known that surgical procedures within the oral cavity have a greater resistance to infection than extraoral surgery and heal with a peculiar readiness (1). Although not desirable, should there be local necrosis about a burr hole due to overheating or corrosion, the entire procedure is not jeopardized, because the holding power of direct wiring does not depend on rigid adaptation of the bone to the wire. Reduction is by direct visualization of fragments and fibrous tissue interposing is readily seen and removed. Cosmetic effect is excellent during repair (Figs. 5,d and 6,g). There is no disfiguration from operation. If other fractures exist in the presence of teeth away from the edentulous area, these can be treated by the usual accepted methods (Figs. 5,c,e). Direct wiring allows for function (Fig. 6,f).

According to the technique as advocated by Kazanjian (5), wire passed through drill holes in the fractured parts is used to hold them in proper place until after consolidation, at which time the wire is removed. To facilitate this removal, Kazanjian recommends leaving the twisted ends of the wire projecting through the mucosa.

However, the use of inert metals in surgery is now well established. The recent investigations of Campbell, Meirowsky, and Hyde have shown that ticonium is not cytotoxic either *in vitro* or *in vivo*.

Fig. 1. a and b, Roentgenogram and photograph of patient showing skeletal fixation applied. (Courtesy of C. W. Waldron, J. Oral Surg.)

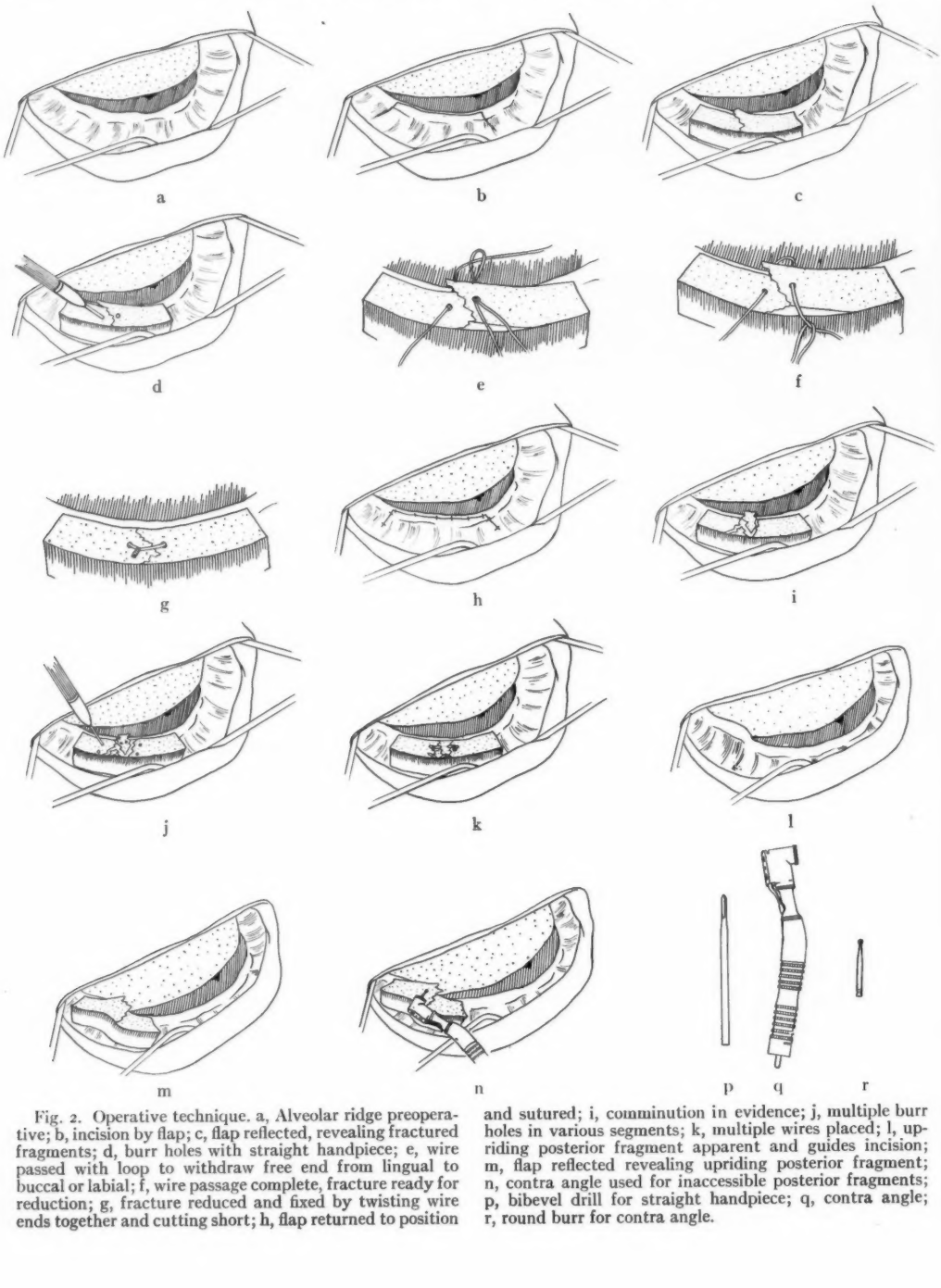


Fig. 2. Operative technique. a, Alveolar ridge preoperative; b, incision by flap; c, flap reflected, revealing fractured fragments; d, burr holes with straight handpiece; e, wire passed with loop to withdraw free end from lingual to buccal or labial; f, wire passage complete, fracture ready for reduction; g, fracture reduced and fixed by twisting wire ends together and cutting short; h, flap returned to position and sutured; i, comminution in evidence; j, multiple burr holes in various segments; k, multiple wires placed; l, upriding posterior fragment apparent and guides incision; m, flap reflected revealing upriding posterior fragment; n, contra angle used for inaccessible posterior fragments; p, bibevel drill for straight handpiece; q, contra angle; r, round burr for contra angle.

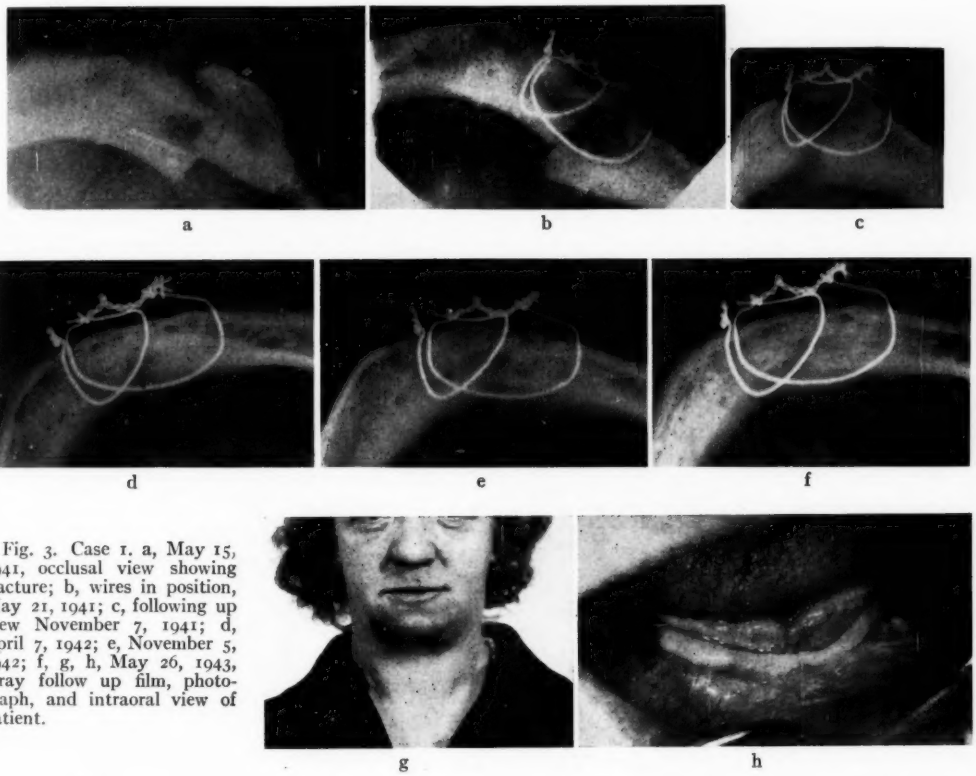


Fig. 3. Case 1. a, May 15, 1941, occlusal view showing fracture; b, wires in position, May 21, 1941; c, following up view November 7, 1941; d, April 7, 1942; e, November 5, 1942; f, g, h, May 26, 1943, x-ray follow up film, photograph, and intraoral view of patient.

Likewise Key has suggested that the 18-8-S-MO stainless steel is suitable, and Pudenz that tantalum is the wire of choice because, in addition to its passivity, it has added properties of workability which make it desirable.

This passivity was first described by Faraday as due to the protective oxide film. Grave, Adler, Rathert, and Schmidt propounded the "Hydrogen Solution Theory of Passivity" and Wulff and Uhlig propound the "Electron Sharing of Metal Atoms Theory."

Whereas direct fixation as described by Kazanjian (5) might be the ideal ocedure, there may be instances in which removal of the wires several weeks or months after insertion is not convenient due either to the position of the wire, conditions on the battlefront, or the undesirability of secondary surgical procedure, even though minor. With this in mind the cases described below were treated by the following technique:

An incision is made along the alveolar ridge over the site of the fracture (Figs. 2,a,b). The mucoperiosteum is reflected, revealing the fractured fragments (Fig. 2,c). Burr holes, made with a bibevel drill 1.5 millimeters (Fig. 2,p) or a round burr No. 5 or No. 6 (Fig. 2,r) are made. A straight handpiece (Fig. 2,d) is used in the forward part of the mouth. A contra-angle (Fig. 2,q) is used posteriorly (Figs. 2,l,m,n). Wires of known passivity are passed through these holes (Fig. 2,e). One difficulty to be anticipated is passing wire from the lingual aspect buccally. This is minimized by the passing of a looped wire to receive the free end to be drawn back within the loop (Fig. 2,f). Wires may be placed multiply depending on degree of displacement and number of fragments (Figs. 2,i,j,k). Ends of wires are twisted together and cut short (Figs. 2,g,k). The flap is returned to place and sutured (Fig. 2,h).

CASE 1. A 37 year old, married housewife, was admitted to the hospital on May 13, 1941, with a compound fracture of the edentulous mandible and fractured lower right fibula and tibia following an automobile collision. Figure 3,a is an occlusal x-ray view. On May 17, direct wiring of the man-

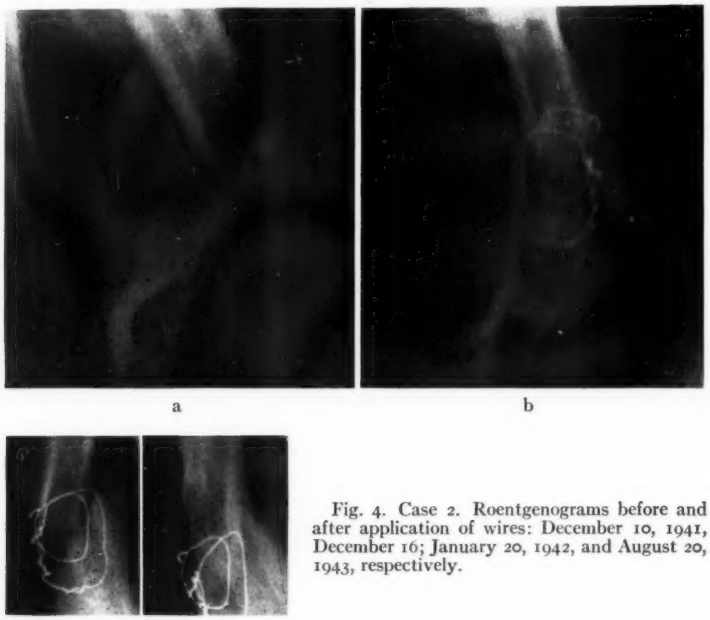


Fig. 4. Case 2. Roentgenograms before and after application of wires: December 10, 1941, December 16; January 20, 1942, and August 20, 1943, respectively.

dible was carried out with intraoral approach. The operators were Drs. M. S. Strock and A. E. Strock. Ticonium wire was used. The constituents of this alloy in its wrought form is: nickel 36.2 per cent, colbalt 29.6 per cent, chromium 28.2 per cent, molybdenum 6.0 per cent.

Although not obvious in the original x-ray view, there was comminution. A loose sliver of bone 15 centimeters in length was removed. The various fragments were wired together and the mucosa was sutured in place over the wire. Figure 3,b shows the wires in position. Hospital course was uneventful as has been the course since then. The wires have not been removed. There are no subjective symptoms. The early anesthesia of the mental area has disappeared. Figure 3,c is a follow-up x-ray view taken November 7, 1941. At this time the clinical picture was normal. Figure 3,d is a similar view taken April 7, 1942; Figure 3,e, a view taken November 5, 1942; Figure 3,f, a view May 26, 1943. Repair of the fracture and toleration of wire are apparently complete. Figure 3,g is a photograph of the patient on May 26, 1943, and Figure 3,h, an intraoral view at the same time. The continuity of the mandibular cortex verifies the fact that contact of the fragments rather than perfect apposition of the parts is necessary in treating fractures of this type.

Case 2. Patient, W. G. G., 64 year old white, married Vermont farmer entered the hospital for the first time December 7, 1941 because of fractured jaw allegedly received in an automobile accident 9 days previously. Treatment had been attempted unsuccessfully elsewhere.

Physical examination showed a temperature of 100.6 degrees; pulse, 118; respiration, 22. Multiple urine examinations were essentially negative. Mouth swab culture showed many Staphylococcus aureus and Streptococcus viridans. Admission white count was 14,000, red blood cells 5.06; polymorphonuclears, 79 per cent. Subsequent white count was 8,900. Hinton positive on admission; Wassermann, negative. Subsequent check negative Hinton and negative Wassermann.

Right anteroposterior and posteroanterior stereoroentgenograms of the skull showed a badly comminuted fracture of the mandible with several oblique fractures in the region of the angle at the left mandible and a transverse fracture on the horizontal ramus of the right mandible nearer the symphsis; also, comminuted fractures of the wall of the left antrum; considerable clouding of the antrum. The skull was apparently intact. This report was signed by M. C. Sosman.

On December 12, 1941, Dr. M. S. Strock, operated. The patient was premedicated on the ward with 10 milligrams of morphine sulfate. Avertin was administered and the patient was brought to the operating room in the dental chair in the upright position, unconscious. His face and mouth were prepared in the usual way, and drapes were then applied. Nasal tubes were passed to assure a clear airway. Anesthesia was obtained in the lower right jaw by the injection of 2 per cent procaine, buffered, containing 3 drops of adrenalin chloride to 30 cubic centimeters. The injection was made at the right mandibular foramen.

It was noted at this time that there was marked overriding of the bony fragments on the lower right side, and that the mucous membrane was entirely healed at the site of the original perforation. When all was in readiness, a heavy towel clip was fastened to the anterior segment. An incision was made along the upper border of the right jaw, and the soft tissue on the buccal and lingual aspect was dissected. Good exposure of the fractured area was obtained and the fibrous union was broken by means of blunt dissection. By means of a dental burr two holes were drilled in the mesial and two were drilled into the distal segments. The segments were then approximated and immobilized

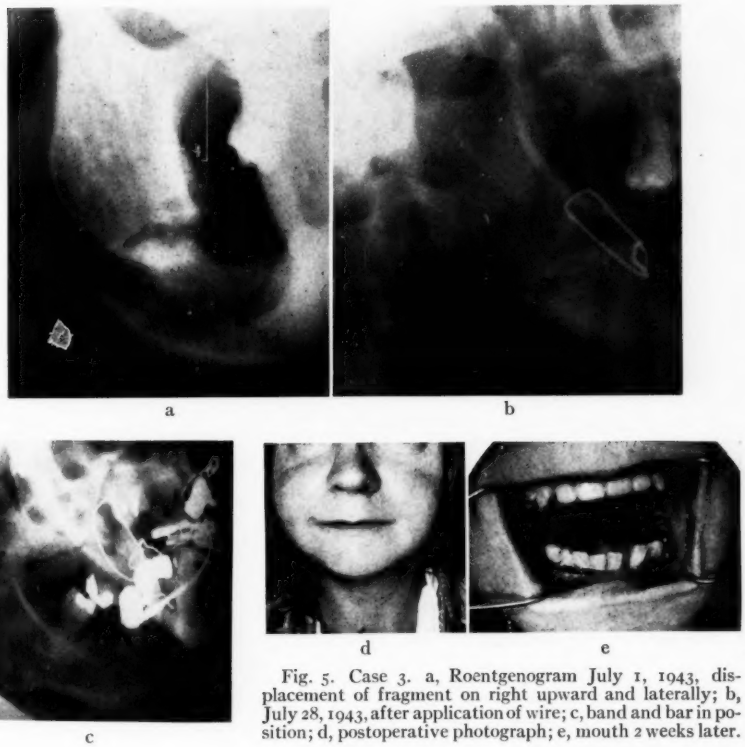


Fig. 5. Case 3. a, Roentgenogram July 1, 1943, displacement of fragment on right upward and laterally; b, July 28, 1943, after application of wire; c, band and bar in position; d, postoperative photograph; e, mouth 2 weeks later.

with two separate pieces of ticonium wire. The excess wire was cut away and the free ends were tucked in toward the bone. The soft tissues were then approximated and held in position with black silk sutures. The result at this time appeared quite satisfactory. At the beginning of the operation the patient's blood pressure rose to over 210, and remained unevenly elevated until the close of the operation. On several occasions the patient became cyanotic. This was immediately relieved by the extension of the tongue and of the anterior segment of the jaw. There was no unusual bleeding at the close of the operation, and the patient left the operating room in good condition. Recovery was uneventful. The patient's progress was good and he was discharged as improved from the hospital on the 8th postoperative day. Figures 4,a,b,c, and d are preoperative and postoperative roentgenographic views.

CASE 3. Patient F. W., 36 year old housewife, entered Peter Bent Brigham Hospital on surgical derision for first time. She was suffering from a swollen painful jaw. She was knocked to the ground 4 days before admission and the day before the right lower molar was extracted following which extraction she had severe pain, and was unable to sleep and eat. Her temperature was 101 degrees; pulse, 96; respiration, 20. Hinton was negative. Urine examination was essentially negative. Red count was within normal limits; white count 10,600 on admission, falling to 6,300 on discharge. On admission differential was 82 polymorphonuclears. Fasting blood sugar was 97 milligrams per cent; diazine level, 12.8 and 18.9 milligrams per cent.

X-ray report on July 1, 1943 revealed bilateral fractures of mandible transversely through the canine region on the left, obliquely through the molar region on the right. The posterior fragment on the right was displaced upward and laterally (Fig. 5,a). The fragments on the left were in excellent position. July 2, 1943, stereoroentgenograms of the chest showed a bronchopneumonic patch at the left base anteriorly just above the apex of the heart. The right lung was quite clear. The heart was not displaced. No foreign body was demonstrable. (M. C. Sosman.)

On July 9, 1943, irrigation and drainage of the left submental area, planned to be done with electrosurgical scalpel, was done with knife when tube blew on direct current. Discharge was good and area was obviously connected with the mandibular left cuspid in the fracture site. This tooth is to be extracted at the time of wiring which is being delayed due to patient's pneumonia. Ethyl chloride was used as spray for anesthesia. The patient is obvious candidate for general anesthesia at time of wiring.

On July 20, 1943, under ether anesthesia, the badly displaced edentulous fragments of the right side of the fractured mandible were laid bare by an incision along the alveolar crest. Burr holes were made on either side of the fracture. Fibrous tissue was removed from the fracture site. Tantalum (element Ta) wire .020 gauge was passed through the holes, and the fracture was reduced. Mandibular left cuspid was then extracted and a Kazanjian type band and bar were placed with the band on the lower left second bicuspid. Tantalum wire buttons made by twisting strands

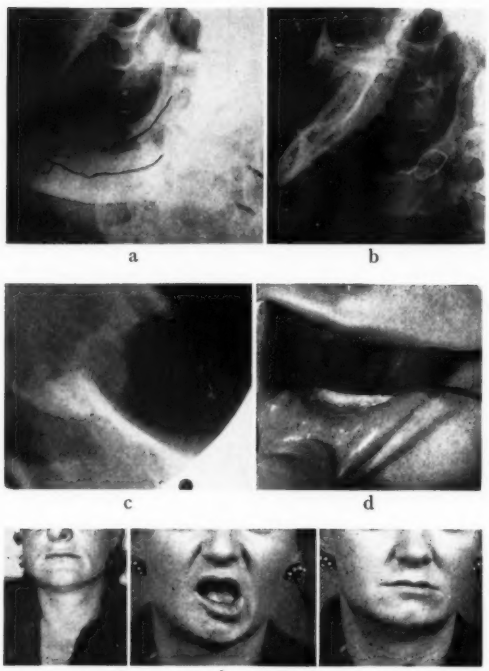


Fig. 6. Case 4. a and c, Operative views; b, wires in place; d, after reduction of fracture; e, postoperative view; f and g, 7th postoperative day.

of wire on themselves, were placed right and left. The wire on the right side was then twisted taut and cut short (Fig. 5,b). This procedure was left to be done at this time to avoid manipulation during band and bar placement (Fig. 5,c). Flaps were then returned to position and sutured. Elastics were placed. Patient left operating room in good condition. Figure 5,d is a postoperative photograph.

Patient developed marked edema of the right side of the face which subsided promptly and she was discharged from the hospital on the 8th postoperative day. Figure 5,e is a photograph 2 weeks later.

CASE 4. Patient O.S.D., 39 year old widow, was admitted to this Hospital October 9, 1943, from the Faulkner Hospital where she had regained consciousness after the automobile she was driving collided with a hydrant.

On admission the red blood cells and hemoglobin were normal; white blood cells numbered 13,000. Differential count was 82 per cent polymorphonuclears with 18 per cent lymphocytes; smear was normal; urine, normal; total protein, normal; lumbar puncture showed 68 red blood cells, 60 lymphocytes.

X-ray report (Figs. 6,a,c), October 9, 1943, was as follows: Films of the right mandible showed a complete transverse comminuted fracture through the mandible just above the angle. There was overlapping of the fragments, the proximal fragment being anterior to and above the ramus. Anteroposterior view showed comminution with a loose fragment from the lateral cortex. The mandible elsewhere appeared normal. There was no fracture of the condyloid process or neck on the left. The skull appeared normal with no evidence of fracture elsewhere. (M. C. Sosman.)

On Oct. 14, 1943, the patient was premedicated with atropine sulfate 0.0003 gram and morphine sulfate 0.0018 gram, 1 hour before being brought to the operating room where the usual drapes were applied with patient reclining in the dental chair. The right inferior alveolar nerve was blocked with 1 per cent monocaine. Infiltration for anesthesia of the long buccal nerve was also carried out. The throat was packed off and with suction handy an incision was made along the crest of the alveolus of the right mandibular molar area extending back into the retromolar area over the obviously displaced fractured fragments which were readily revealed when the mucoperiosteum was reflected. There was little evidence of any fibrosis. By means of a straight handpiece and bibevel drill, burr holes were made in either side of the fracture site. Tantalum wire, No. 0.020, was passed through these holes, the fracture was reduced and while held in this position the wire was twisted up taut (Fig. 6,b). Flaps were returned to place, sutured with silk (Fig. 6,d). Pressure bandage was applied to keep the edema down. Patient withstood operation well and left operating room in good condition.

The patient's progress was good and he was discharged from the Hospital on the 5th postoperative day. Figure 6,e is a postoperative view, and Figure 6,f and g are photographs on the 7th postoperative day.

SUMMARY

Direct fixation is the method of choice in fractured edentulous mandibles in cases in which displaced fragments are present and accessible. Wiring of this type obviates the necessity for skeletal fixation in most instances of mandibular fracture without tissue loss. In view of the known toleration of various inert metals, it is advisable that wires made of these inert substances, such as ticonium and tantalum, be used whenever direct fixation of the fractures is indicated. When so used it can be done with assurance that these wires may be placed without the necessity of planning their removal, should it be so desired.

REFERENCES

1. BERNIER, J. L., and CANBY, C. P. J. Am. Dent. Ass., 1943, 30: 188–197.
2. CAMPBELL, E., MEIROWSKY, A., and HYDE, G. Ann. Surg., 1941, 114: 472–479.
3. GILLIES, H. D. Brit. Dent. J., 1941, 71: 351–358.
4. KAZANJIAN, V. H. Personal communication.
5. Idem. J. Am. Dent. Ass., 1933, 20: 757–773.
6. KEY, A. J. Arch. Surg., 1941, 43: 615–626.
7. PUDENZ, R. H. Surgery, 1942, 12: 791–797.
8. RUSHTON, M. B., and WALKER, F. A. Am. J. Orthodont., 1942, 28: 135–143.
9. SHAAR, C. M., and KREUZ, F. P. JR. Surg. Clin. N. America, 1942, 22: 1537–1538.
10. STROCK, A. E. Paper read before International Society for Dental Research, New York, March, 1942.
11. WALDRON, C. W. et al. J. Oral Surg., 1943, 1: 59–83.
12. WALTER, C. W. Personal communication to the author.
13. WAUGH, R. L. Personal communication to the author.
14. WULFF, J., and UHLIG, H. H. Met. Tech., June, 1939; Oct., 1939.

THE PLACEMENT OF INCISIONS IN THE NECK

EMILE HOLMAN, M.D., F.A.C.S., San Francisco, California

OLD, presumably self-evident, truths must be retold occasionally to insure that they be not forgotten. In a recent tour of surgical clinics, I was startled to see at two leading centers transgression of an old axiom that incisions in the neck shall not cross the normal creases of the skin. Although the once standard incisions for thyroidectomy paralleled the inner border of the sternomastoid muscle on both sides of the neck, no present-day surgeon would view them with anything but abhorrence. Similarly, vertical incisions for the excision of branchial cysts, or for the opening of cervical abscesses, should be

From the Department of Surgery, Stanford University Medical School.

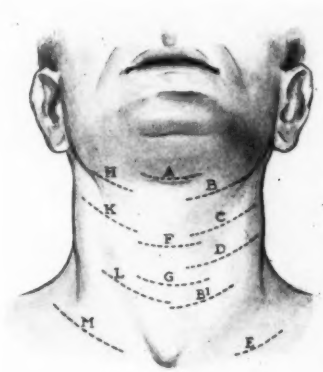


Fig. 1

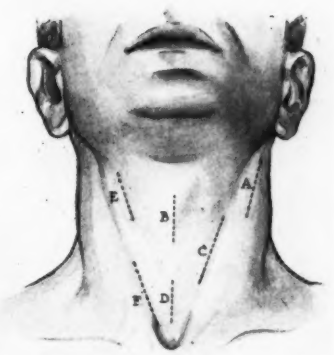


Fig. 2

Fig. 1. Proper placement of incisions in the neck paralleling the normal lines and folds of the skin: *A*, for drainage of submental abscess; *B*, for excision of congenital sinus partially mobilized through incision *B*; *B'* for mobilization of sinus tract presenting at *B'* but penetrating pharynx at *B*; *C*, for excision of carotid tumor or branchial cyst; *D* for diverticulum of the esophagus; *E*, for scalenotomy or phrenic interruption; *F*, for cricothyreotomy; *G*, for tracheotomy; *H*, for drainage of cervical abscess at angle of the jaw; *K*, for exposure of internal or external carotid; *L*, for exposure of common carotid; *M*, for exposure of brachial plexus.

Fig. 2. Placement of incisions as recommended in a recently published textbook (1943) illustrating modern surgical technique, all of which transgress the rule not to cross creases of the skin in the neck: *A*, for excision of a carotid tumor; *B*, for cricothyreotomy; *C*, for lateral esophagotomy; *D*, for tracheotomy; *E*, for exposure of the external carotid artery; *F*, for exposure of the common carotid artery.

viewed with an instinctive aversion by all surgeons.

An incision that crosses the normal lines of the skin in a region characterized by constant motion as in the neck will almost invariably produce a thick unsightly scar that is likely to become more prominent as time passes and that may even assume the character of a keloid. The placement of incisions in the neck, therefore, is particularly important in women, who may suffer untold mental anguish from badly placed incisions that produce keloidal scars in conspicuous and constantly self-observed areas.

In reviewing special articles and textbooks (Fig. 2) on operations for parotid tumors, for esophageal diverticula, for ligation of the carotid vessels, for laryngectomy, it is obvious that many surgeons though aware of the necessity of employing an incision for thyroidectomy that parallels the normal folds of the skin, do not apply this knowledge in their surgical approach to other structures in the cervical region. The point need not be belabored further. Every effort should be made to place an incision for any of the operative procedures named in a crease of the skin, or paralleling a crease if necessity demands that the incision be placed where no crease exists. However, we have no hesitancy—except in draining abscesses—to reflect skin flaps either upward or downward for 1 or 2 centimeters more if thereby the incision can be made to coincide with a normal crease in the skin demonstrable before operation.

In the removal of a congenital sinus which presents in the neck above the clavicle and extends upward to penetrate the pharynx in the region of the tonsil, adequate exposure is easily obtained through two transverse incisions paralleling the skin creases (Fig. 1, *B* and *B'*), and these should be used in preference to a vertical incision paralleling and following the sinus tract, as is so often advised. A temporary tracheotomy can be performed through a transverse incision (Fig. 1, *G*) with minimal residual scarring, whereas the scar of a vertical incision may be an aggravation forever to its possessor. The ligation of the carotid artery, whether common or internal, can be performed as readily through skin-crease incisions (Fig. 1, *K* and *L*) as through incisions paralleling the sternomastoid muscle, and the scars after several months are almost nondetectable. After the skin flaps are reflected, the muscle is retracted laterally and not divided. Similarly, branchial cysts, esophageal diverticula, carotid body tumors (Fig. 1, *C* and *D*) may be removed through crease-paralleling incisions permitting wide reflection of skin flaps and retraction of the muscle for adequate exposure. Incisions for the draining of cervical abscesses, wherever located, will heal with minimum scarring if placed parallel to the normal lines of the skin (Fig. 1, *A* and *H*).

Careful closure of the platysma muscle with interrupted fine silk or cotton sutures is a necessary part of a nonscarring incision in the neck. Sutures closing the skin should be removed in 48 hours to avoid producing transverse scars and permanent cross-hatching at the site of each suture.

These suggestions are made only as reaffirmations of the teachings of painstaking surgeons of the past, teachings which long since should have become universally recognized as fundamental in the art of surgery. The reproaches of a sensitive woman should be avoided by the surgeon called upon to perform an operation in an area so interminably visible to her.

VENTRAL HERNIA DUE TO NORMAL BANDING OF THE ABDOMINAL MUSCLES

LEO M. ZIMMERMAN, M.D., F.A.C.S., Lieutenant Commander, M.C., U.S.N.R.;
BARRY J. ANSON, Ph.D. (Med.Sci.); EDWARD H. MORGAN, Lieutenant,
M.C., A.U.S., and CHESTER B. McVAY, Lieutenant, M.C., A.U.S.

THE term "ventral hernia" is applied to all protrusions of abdominal content through the anterolateral wall, other than through the inguinal or umbilical orifices. The traumatic defects, including those which follow surgical operations, will not be considered in this discussion because they are not directly based upon anatomical predispositions. The spontaneous hernias, however, are due to a variety of structural deficiencies in the musculoaponeurotic layers of the abdominal wall, most of which have not been adequately explained. Included in this group are hernias of the midline (hernias of the linea alba, or epigastric hernias); and the lateral ventral hernias, comprising the lumbar group, those of the semilunar line, and those due to "banding" of the fibers of the internal oblique and transversus abdominis muscles. This study is particularly concerned with the last named variety, and with the anatomical peculiarities which predispose to them.

Earlier articles by the authors have presented the special anatomical features of the lower inguinal and funicular portions of the abdominal layers (especially, Morgan and Anson, 1942; Morgan, Anson, and McVay, 1942); the present paper is concerned with the nature of the same layers in the territory just superior to that in which direct and indirect hernias occur. In this stripe between the level of the so called aponeurotic inguinal falx and umbilicus, the internal oblique layer is subject to striking departures from the accepted form, while the external oblique and the transverse abdominal exhibit less profound aberrancies.

ANATOMICAL STUDIES

Material and methods. In a general study of inguinal anatomy, body-halves totaling 500 have been examined to date. The statistical results of this investigation will be presented later[1]; interest now centers in the occurrence of aponeurotic muscular arrangements that predispose to weakness against parietal herniation. Appropriate clinical aspects will be discussed, based upon experience in the management of such hernias.

In studying inguinal anatomy in the 250 consecutive adult specimens, male and female, the outstanding features of each of the three anterolateral musculoaponeurotic layers were recorded in full sized measured sketches. These permanent records were employed as material for cataloging "types" of inguinal parietes and for recording incidence of certain selected elements. For the present article data on character of the internal oblique were employed; 3 particularly favorable specimens were used for illustrations (Figs. 1 to 3).

Observations and discussion. External oblique. The chief respect in which this outermost of the muscle layers exhibits variability is in the length and width of the triangular hiatus between the crura of the subcutaneous inguinal ring (Fig. 3b, internal view of cleft). This may extend, at its lateral or apical part, to the anterior superior iliac spine, or it may reach a point only midway between the latter and the pubic tubercle. As the length of the fault increases, laxity of the intercrural wall of fascia, of course, becomes greater. But whether the interval be short or long, there exists potentially a large subaponeurotic space into which a herniating mass may press. This areolar plane, or "space," extends almost to the midline of the abdomen, since the inguinal union of aponeuroses of external and internal oblique muscles takes place not along the lateral border of the rectus muscle but in virtually a median position (Figs. 1 and 2). This space could be occupied by a hernia of parietal character.

Internal oblique and transverse abdominal. The internal oblique layer is figured in all standard textbooks of gross and of applied anatomy as a layer of simple uniformity. Its muscular portion is pictured as being a stratum of evenly distributed fascicles except where distally these fibers may be carried downward upon the spermatic cords (Figs. 1, b and 1, c). But actually such an arrangement fails to appear in many specimens. The in-

A contribution from the Department of Surgery and the Department of Anatomy, Northwestern University Medical School, Chicago, Ill. The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large; similarly, they are not official for the Army.

[1]Article in preparation by E. H. Morgan, B. J. Anson, C. B. McVay, and R. R. Wright.

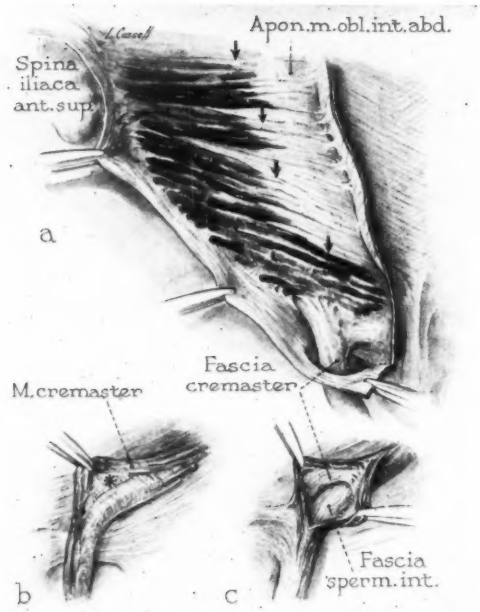


Fig. 1. Inguinal part of internal oblique muscle. Specimen of a well developed adult white male. a, Medially, the external oblique aponeurosis has been cut along the line of continuity with that of the internal oblique and, inferiorly, near the inguinal ligament, sparing medially the subcutaneous inguinal ring. The bands of the internal oblique are indicated by arrows. b, The aponeurosis of the external oblique muscle (opposite side of same subject) has been incised through the superior crus of the ring and turned inferiorly to expose the internal oblique muscle. The muscle sends few fascicles downward upon the cord, the remainder of the cremasteric investment being fascial. c, The cremasteric fascia has been incised and the margins have been drawn aside to expose the internal spermatic fascial layer of the cord.

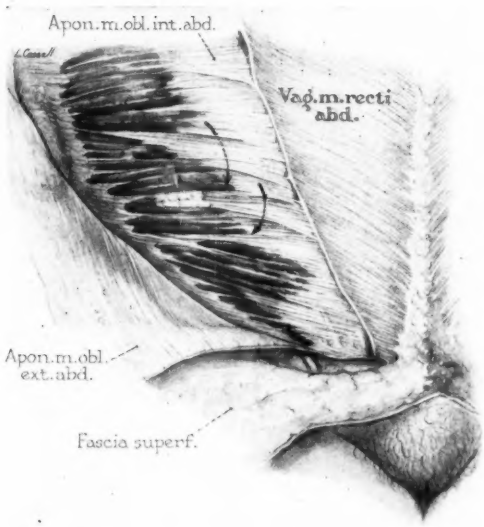


Fig. 2. Inguinal part of internal oblique muscle. Specimen of a well developed adult white female. The external oblique has been incised and turned aside, as in Figure 1, a. The muscle is very definitely banded (arrows pass beneath two prominent bands).

ferior fascicles may lie cranial to the level of the inguinal canal, the cremasteric or funicular layer then being wholly fascial (Fig. 1, a). Furthermore, the main, or parietal, part of the stratum may consist of separate musculoaponeurotic bands held together by the external and internal investing fascial layers.

Three selected adult specimens will serve to demonstrate these features. Two are well developed males (Figs. 1, a to 1, c and Fig. 3), the other an equally favorable female cadaver (Fig. 2). The internal oblique muscles in the male specimens are strikingly banded (Fig. 1, a at arrows; Fig. 3, a at boundaries of space marked by asterisk). The lowermost is likely to remain muscular to the point of fusion of the aponeuroses of the external and internal oblique muscles where these layers contribute to the formation of the rectus sheath (Fig. 1, a, Fig. 2). The other bands are usually shorter, terminating along a vertical line which is lateral to the outer margin of the rectus muscle. The bands generally are arranged like the blades of a slightly opened fan, with the interspaces increasing as the medial extremities are approached. The internal oblique layer in the female specimen is likewise banded. Two of these stand out prominently (Fig. 2, arrows), since their course is more oblique than that of the bands which they overlie. The bands are separable from subjacent tissue to the point where they fuse with aponeurosis of the external oblique.

In the authors' study of 500 body halves, defects of this nature, which conceivably could permit of parietal herniation, were found in 109 (21.8%). These deficiencies took the form of slit-like gaps between divergent bundles of fibers. The investing fascial layers of the internal oblique bridged the defects; the fascia often contained small masses of fat. Sometimes herniations of fatty preperitoneal tissue passed through the transversus layer to occupy the defects in the internal oblique stratum (Fig. 3, a, labelled). The width of these defects varied between 0.2 and 1.5 centimeters. In some specimens more than one musculoaponeurotic deficiency appeared (Table I).

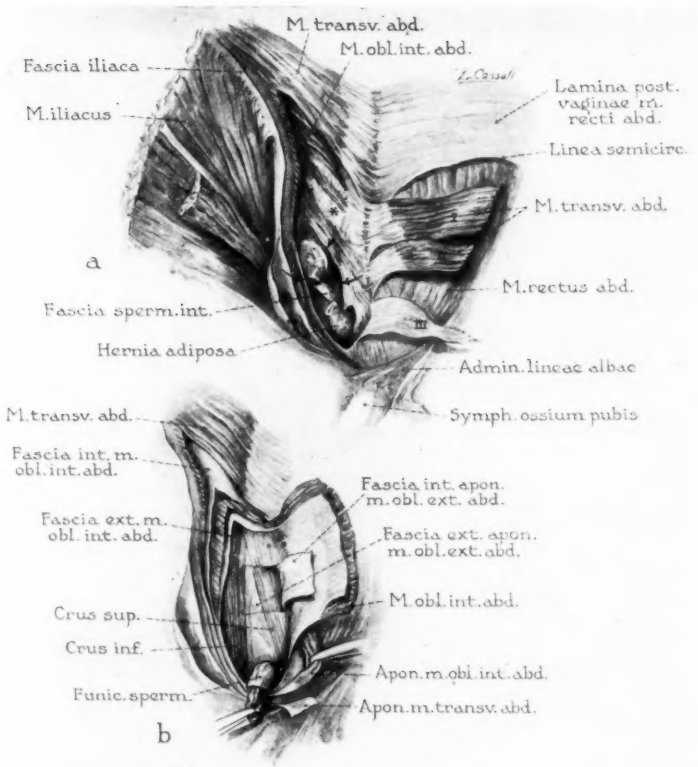


Fig. 3. Posterior aspect of inguinal layers a, internal oblique. A portion of the transversus abdominis has been turned medialward along the line of fusion with the internal oblique. The upper part (slips *I* and *II*) is musculoaponeurotic; the lower part (slip *III*) is entirely fascial, and forms the thin posterior wall of the inguinal canal. The internal oblique is likewise fascial in its lower part (marked by arrows) and is weakened by fatty tissue collected in the area above the cremaster (at *). The hiatus for a hernia adiposa lies just medial to the ring. b, Transverse abdominal muscle (same specimen). The internal oblique has been reflected in the region of the inguinal canal, but the tubular cremasteric prolongation is intact around the spermatic cord. The external oblique aponeurosis is exposed in the area of the intercrural defect in the aponeurosis. The thin external and internal layers of investing fascia are demonstrated by reflecting a small area of the latter. (From Morgan and Anson, 1942.)

The inguinohypogastric portion of the transversus was studied in 165 body halves. Musculoaponeurotic defects appeared in 27 specimens. In 19 instances there was but one defect, and in 8 specimens there were multiple deficiencies. Both in form and in relative size these musculoaponeurotic defects resembled those described for the internal oblique stratum.

For the occurrence of elongate defects in both musculoaponeurotic strata in individual specimens, and for the relations of these defects to each other, 100 body halves were examined (Table II). They were found in one or in both layers in 45 specimens. In 25 specimens one or more defects occurred in the internal oblique stratum alone; in 10 specimens there were one or more gaps in the transversus layer; and in 10 specimens there were defects in both strata. Of this last group a total of 6 specimens possessed superimposed defects. In the remaining 4 the defect in the transversus stratum lay cranial in position to the gap in the internal oblique. It is, of course, in the specimens in which superimposed defects occur (6 in 100 studied) that parietal herniation

TABLE I.—INCIDENCE OF MUSCULOAPONEUROTIC DEFECTS IN INTERNAL OBLIQUE

(500 Body Halves)

Description	Number	Percentage
With 1 defect	74	14.8
With 2 defects	32	6.4
With 3 defects	3	0.6
Total defective	109	21.8

would be most likely to occur. In one such specimen a hernia adiposa from the preperitoneal layer pressed through both the internal oblique and the transverse abdominal.

CLINICAL APPLICATIONS

The anatomical observations described shed important and hitherto unrecognized light upon the genesis and pathology of spontaneous lateral ventral hernias exclusive of the lumbar group. These are usually described as hernias of the linea semilunaris (Spigel). This line is a curved depression extending from the tip of the ninth rib to the pubis, marking the outer edge of the rectus sheath. There are no structural weaknesses specifically peculiar to this anatomical landmark. Quite to the contrary, it represents the line of fusion of the aponeuroses of the internal oblique and transversus abdominis muscles and is, consequently, an area of strength rather than of weakness. There is, therefore, no reason to anticipate the frequent occurrence of hernias along this line.

The linea semilunaris is defined somewhat differently in discussion of semilunar line hernias. In a recent presentation of the subject, River (1942) states "the linea semilunaris is the line of transition between the muscle bundles and aponeurosis of the transversus abdominis muscle." The anatomical studies of Anson and his associates have demonstrated a very wide variation in the relative amounts of muscle and aponeurosis in the transversus layer, and the line of their transition in no way coincides with the anatomically defined semilunar line. The area described does coincide, however, with the zone under discussion in this study in which defects occur due to banding of the muscle fibers of the internal oblique and transverse abdominal muscles.

Most of the hernias of the linea semilunaris are further described as occurring at or below the level of the semilunar fold of Douglas. This coincides with the distribution of defects in the muscular layers described herein, and would suggest that they fall into two categories. Those that appear inferior to the lowermost fibers of the internal oblique would fulfill the requirements of diverticular direct hernias; those emerging above this

TABLE II.—INCIDENCE OF DEFECTS IN INTERNAL OBLIQUE AND TRANSVERSE ABDOMINAL ALONE OR TOGETHER AND SUPERIMPOSED

(100 Body Halves)

Description	Number	Percentage
Defect in one or both layers	45	45
Defect in internal oblique alone	25	25
Defect in transverse abdominal alone	10	10
Defects in both layers	10	10
a) Superimposed defects	6	
b) Defect in transversus cranial to that in internal oblique	4	
Total defective	100	

level would conform with the type here discussed, i.e., herniation between banded or segmented muscle fibers of the internal oblique and transverse layers.

In the genesis of spontaneous lateral ventral hernias, in addition to the congenital anatomical predispositions, factors which increase abdominal tension are contributory. Prominent among these are obesity, pregnancies, ascites, chronic coughs, and severe muscular effort. These hernias are not infrequently associated with other types of abdominal hernia.

The hernial ring in such cases is usually a sharply defined defect in the transversus aponeurosis which rarely exceeds 2 centimeters in diameter. The sac is often preceded by a lipomatous mass of preperitoneal fatty tissue. The hernia is frequently interparietal, penetrating the transverse and internal oblique layers, and spreading out between the latter and the intact overlying aponeurosis of the external oblique. The contents usually consist of omentum and small bowel; and incarceration or strangulation are not common.

Spontaneous lateral ventral hernias may cause no symptoms. Some, however, are accompanied by distress which may be mild or severe and which is aggravated by standing or straining, and relieved by reduction of the hernia. The mass may not be palpable if it is small and interparietal in position although a swelling or resistance is usually discernible in incarcerated or strangulated hernias. Tenderness over the mass or over the defect in reducible hernias is considered a characteristic finding.

The only available treatment for lateral ventral hernias is surgical repair. The operation requires first the exposure of the mass. Since its position is often interparietal, this frequently necessitates division of the aponeuroses of the external oblique. The subjacent sac and its attached lipomatous mass of preperitoneal fat must then be dissected free from the surrounding muscular and fascial

structures down to the level of the preperitoneal areolar layer. The sac should be opened and its contents reduced. Adherent omentum may have to be resected between ligatures. The sac is then closed by transfixion or suture, and its stump returned to the preperitoneal space.

Closure of the hernial defect is effected by defining the hiatuses in the transverse and internal oblique layers and obliterating them by suture. As has been stated, the ring is small, and usually no difficulty is encountered in approximating the fascial edges. In rare instances of large hernias and poorly developed tissues, fascial sutures or transplants of fascia might conceivably be of value. The apposition of a firm reunited external oblique aponeurosis usually provides sufficient reinforcement to obviate the need for further operative manipulation.

Personal observations. In addition to the potential and actual hernias through defects due to banding of the transverse abdominal and internal oblique muscles which were found in the anatomical studies described herein, we have encountered 3 such cases at the operating table during the past few years. The first 2 occurred before the anatomical basis for them had been worked out. The most recent one was made clear by these studies, and careful inspection proved it to coincide in every respect with the anatomical findings herein presented in detail (Fig. 4).

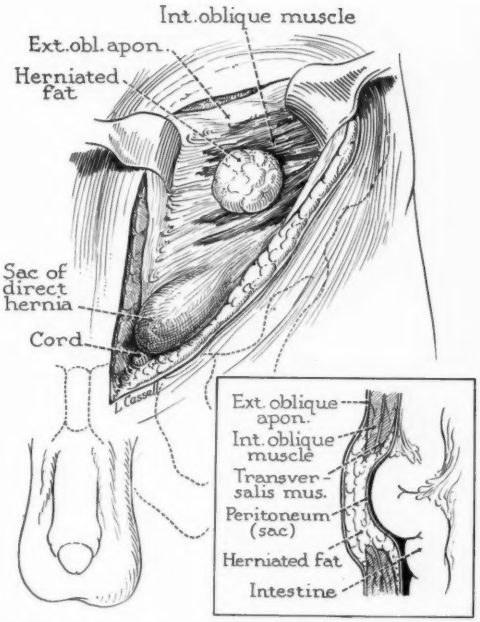


Fig. 4. Surgical case; from drawing prepared at operation. Inset, section showing relation of intestine and of subperitoneal fat to the muscular margins of the parietal defect.

The patient in this case was a young man who entered the hospital because of bilateral direct hernia. The internal oblique muscle was very poorly developed, its lower fibers ending at the level of the internal rings. On the left side a wide gap was seen between bands of muscle fibers of the internal oblique, about 1.5 inches (4 cm.) above the internal ring, through which protruded a fatty mass. Exploration disclosed a long, pedunculated preperitoneal lipoma which preceded a peritoneal hernial sac. The hernia emerged through a sharply defined ring in the transversalis fascia, passed through a defect between bands of muscle fibers of the internal oblique, and spread itself interparietally between the internal oblique and the intact external oblique aponeurosis.

The sac was opened and inspected. There were no adherent contents. It was then dissected free from the internal oblique and transversalis layers and closed by transfixion at its base, with a fine silk suture. The sac and lipoma were excised and the stump reduced into the preperitoneal space. The hiatus in the transversalis fascia was closed by silk suture, and the gaping fibers of internal oblique approximated with interrupted sutures. The direct hernia was repaired by the method described by one of us (Zimmerman, 1938), and the external oblique aponeurosis was closed over both the inguinal and ventral hernias. The patient made a totally uneventful recovery, and when last seen was free from recurrence of any of the hernias.

The other 2 cases observed were in women, both of middle age and both obese and multiparous. Operation was undertaken because of poorly defined swellings in the lower abdomen, which were associated with discomfort on exertion and tenderness to pressure. In both, spontaneous ventral hernias of this type were found emerging through the internal oblique triangle and lateral to the linea semilunaris. The bulk of the mass was made up of extraperitoneal adipose tissue.

It is entirely probable that spontaneous ventral hernias of this type are far more prevalent than the very small number of reported cases would imply. Our own experience, both in the anatomical laboratory and the operating room, indicates that they are not rare. It is hoped that bringing them to the attention of surgeons and establishing their pathogenesis will result in a more frequent recognition and reporting of this type of hernia.

SUMMARY

Far from being a series of layers whose features can be presented adequately and correctly in a conventionalized account, the anterolateral abdominal muscles display such marked departures from an anatomic norm that consideration of at least the extreme variants is essential to careful diagnosis of hernia and to rational and lasting repair.

Of the three abdominal muscular layers, the external is the least variable; in the inguinal area it is quite uniformly aponeurotic. But the intermediate and deep layers, namely, the internal oblique and the transverse abdominal, are frequently variable; they are often represented only by fascia in their inferomedial extent, or disposed in the form of oblique musculoaponeurotic bands bound together solely by fascia. In the latter instance narrow segmental stripes of fascia would intervene between wider and heavier ribbons of muscle or of aponeurosis, their weakness offering parietal exit to a adipose mass in the preperitoneal layer, or to omentum or intestine. Where areas of local weakness were superimposed, extrusion would be facilitated. The occurrence of ventral hernia is explainable on these fundamental grounds.

Cases are described in which spontaneous lateral ventral hernias occurred due to such banding of the fibers of the internal oblique and transversus abdominis muscles. Their origins and structural characteristics are fully explained by the anatomical studies herein presented.

REFERENCES

1. Anson, B. J., Morgan, E. H., and McVay, C. B. Q. Bull. Northwest. Univ. M. School, 1942, 16: 128–141.
2. Morgan, E. H., and Anson, B. J. Q. Bull. Northwest. Univ. M. School, 1942, 16: 20–37.
3. River, L. P. Ann. Surg., 1942, 116: 405–411.
4. Zimmerman, L. M. Surg. Gyn. Obst., 1938, 66: 192–198.

THE CORRECTION OF ABNORMALLY PROMINENT EARS

FORREST YOUNG, M D., F.A.C.S., Rochester, New York

THE external ear has certain definite characteristics of contour which are accepted as normal. These may vary within rather wide limits of detail, but on the whole normal ears have certain ridges, depressions, and positions in common. The normal ear may be large or small, its convolutions finely or bluntly chiseled; but on close inspection the configurations are found to follow a definite plan. Moreover, the position of the normal ear on the head is constant within fairly narrow limits. To be normal, the configurations of the two ears must be the same; but of far more importance, the position on the head must be such that they are symmetrical.

The normal relation of the ear to the head is usually expressed by stating that the ear rests on the head at an angle of about 30 degrees. From the reconstructive viewpoint more information is conveyed and better appreciation of the criteria to be fulfilled is indicated if one considers the external ear as two separate structures; the conchal portion, and the scapha. The dividing line between these two portions is the antihelix.

If one views the normal ear from above, it is noted that the conchal portion forms an angle of approximately 90 degrees with the head, and the scapha in turn forms another angle of about 90 degrees with this (Fig. 1, a). The rim of the ear then curves outward as the helix. The conchal-head angle varies very little. The angle between the scapha and the concha may vary as much as 10 to 15 degrees to either side of a right angle and still not appear abnormal.

From in front the posterior wall of the conchal hollow, the ridge of the antihelix, and the helix are all seen. The helical rim is seen as an edge just visible beyond and behind the antihelix (Fig. 1, c). If one measures the angle formed by the plane of the ear, as seen from the front, and the side of the head, it varies as does the angle formed between the concha and scapha. It may be the angle of 30 degrees frequently mentioned but in the normal ear is usually less.

From the direct lateral view of a normal ear the entire configuration is visible. The relationship of 90 degrees between the concha and the scapha allows one to see the entire ear including the anterior and superior crura of the antihelix and the triangular fossa (Fig. 2). The lateral view of the ear also shows that the ear has a definite positional relationship to the head as regards its long axis. If the chin is not receding, it is found that the angle formed between the long axis of the ear and the vertical plane of the face is almost a constant of 20 degrees (Fig. 3).

Abnormally prominent ears differ in that from front and rear views one's attention is attracted to the wing-like projection. If the structure of these ears is analyzed, it is found that the difference is almost purely one of the angular relationship of the scapha to the concha. In extremely prominent ears the antihelical ridge may be almost entirely absent and the angle between the concha and scapha as great as 150 to 160 degrees (Fig. 1, b). The conchal relationship to the head is normal. The angle remains about 90 degrees. However, these ears often appear large and this may be due to an actual increase in length of the portion of concha which extends outward from the head to the antihelix.

From this description it can be seen that we disagree with the oft repeated statement that abnormal prominence of the ear is due to an "unusually wide angle between the concha and the mastoid process" (6). In our opinion, the abnormal position is due to an increase in the right angle normally present at the antihelix.

INDICATIONS FOR CORRECTION

The abnormally prominent ear is most objectionable in men. Women can usually cover the projecting ear with appropriate hairdress. The position of the external ear does not affect hearing to an appreciable extent, so that the indication for operation is usually psychologic. Hence correction of the projection is often carried out in children before they reach school age to avoid the problems which arise from ridicule by their schoolmates. Operation at an early age does not interfere with normal growth of the ear.

In addition to the prevention of psychologic handicaps in children there are a certain number of adults who ask to have abnormal projection of the ears corrected for practical reasons. This group includes women whose hair has become so thin that the ears can no longer be covered satisfactorily and men who for one reason or another

From the Department of Surgery, The University of Rochester School of Medicine and Dentistry.

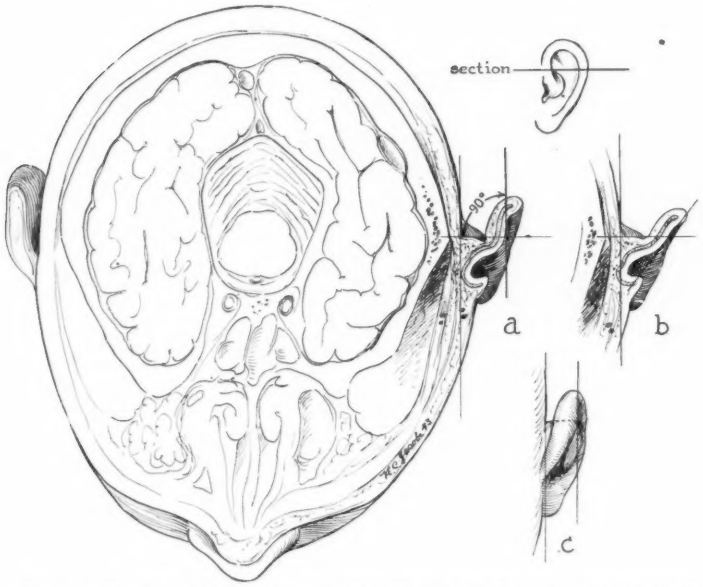


Fig. 1. a, Drawing of an actual cross section of the head from the anatomical laboratory. This section shows the usual angular relationship of about 90 degrees between the head, concha, and scapha. b, Shows an increase of conchal-scaphal angle which would still be within normal limits. c, Shows a normal ear from directly in front. Note that the helical rim is visible.

believe that their noticeable appearance is an economic handicap.

EVOLUTION OF OPERATIVE CORRECTION

We have never seen any appreciable correction obtained by mechanical means. Most children brought by their parents for correction of abnormal protuberance of the ears have had their ears strapped against the head for varying periods as infants, or have worn tight fitting caps at night. Although the position can be corrected by these restraints, the ear immediately returns to its former position on removal of the restraint due to the springlike action of the abnormally angled cartilage.

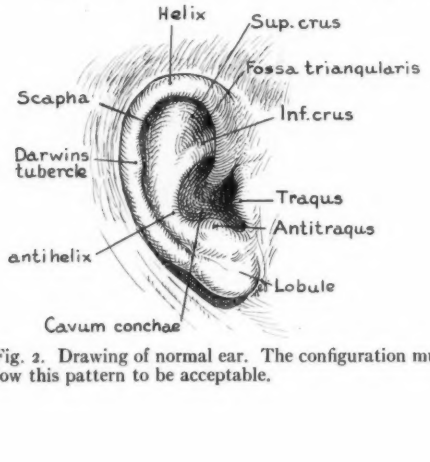


Fig. 2. Drawing of normal ear. The configuration must follow this pattern to be acceptable.

Numerous surgical methods for restoring the widely projecting ear to more normal position have been described. Most of these are of interest only from the historical standpoint, but do show the gradual development of the operation.

The simplest and probably earliest surgical attempt at correction was by the removal of an ellipse of skin from the cephaloauricular angle so that one-half of the skin excised was from the mastoid area and the other half from the ear. The perichondrium of the exposed concha was thus approximated to the mastoid galea when the skin edges were sutured. This operation was rarely permanently successful. The spring of the cartilage gradually pulled the ear back to the original position. Moreover, the removal of an ellipse of skin from the cephaloauricular angle obliterates the normal sulcus to a certain extent. This operation might be successful in young children when the auricular cartilage is very soft and only slight-

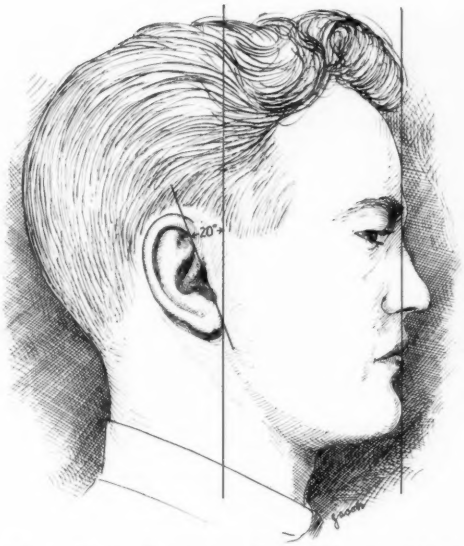


Fig. 3. The ear forms an angle of 20 degrees with the vertical plane of the face. This relationship is almost absolutely constant.

ly deformed. Even then the permanency of the result is questionable. This operation is rarely used at present.

The next logical evolution in operative attempts at correction was the addition of the excision of an ellipse of conchal cartilage corresponding in size to the skin removed. The strip of cartilage was removed near or at the head-ear junction so that the ear as a whole was rotated backward into closer approximation with the head. This operation was described by Morestin in 1903. This operation permanently reduces the appearance of abnormal prominence of the ear when viewed from front and back, although the ear still has abnormal configurations (Fig. 10). It is most successful when the increase in the antihelix angle is minimal. At best it is a compromise correction. The ear is brought closer to the head but the scapha still projects abnormally due to the uncorrected increased angle at the antihelix line. In addition it is objectionable because the excess anterior skin left in the conchal hollow forms a noticeable abnormal ridge, and at times one can see a sharp line in the concha due to the cut edge of the conchal cartilage underneath the skin.

The numerous operations devised to attach the ear to the head without removal of cartilage are evidence that the Morestin procedure was not entirely fault free. Among these are the insertion

Fig. 4. The method described by Davis of marking the line of the antihelix with puncture by a hypodermic needle dipped in methylene blue. In Davis's illustrations the superior crus only is marked. It will be noted that the marking extends along both the superior and inferior crus to outline the triangular fossa.

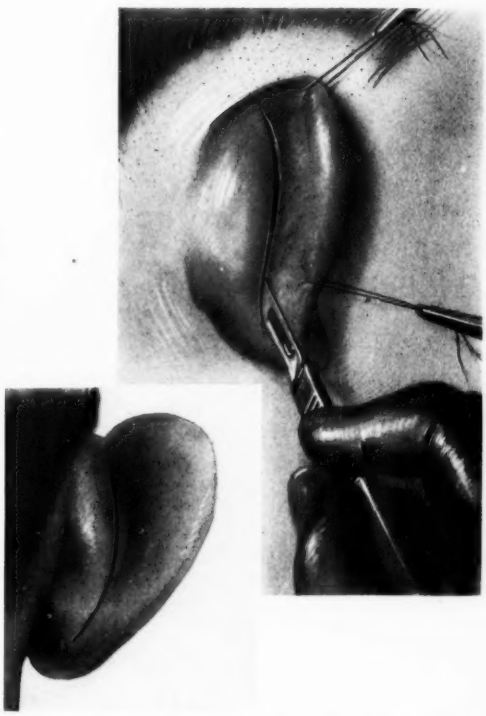


Fig. 5. The operative approach is on the posterior aspect of the ear at the angle between concha and scapha.

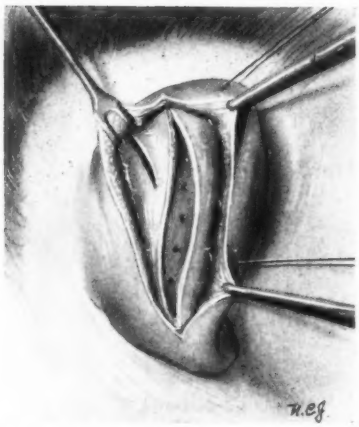


Fig. 6. Incisions are made in line with the methylene blue puncture marks (shown in drawing on undersurface of anterior skin of ear) through the cartilage, with care not to perforate the skin anteriorly.

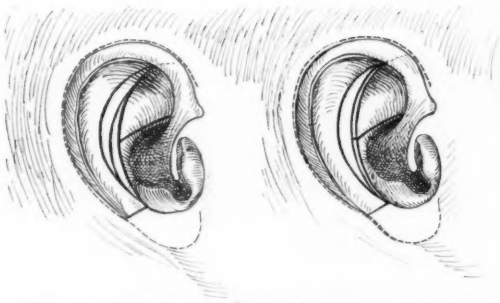


Fig. 7. a, left, Elliptical strips of cartilage are removed. These vary with the deformity. In general a strip is removed in the pinnal region from the scapha to reduce the size of the superior portion of the ear and from the concha in the inferior portion. A narrow strip may be removed from the incision along the inferior edge of the triangular fossa but often the incision alone suffices. b, The projecting edge of the concha forms the antihelix ridge after cartilaginous ellipses have been removed.

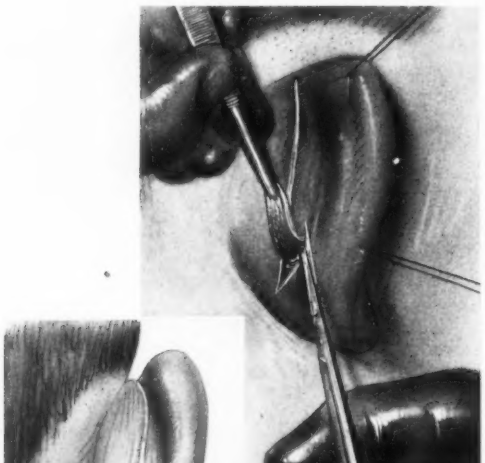


Fig. 8. The scapha is placed on the concha at correct angle and the overlapping skin is excised on the scaphal side—not in the postauricular sulcus. This preserves the normal sulcus and places the scar line at an angle between concha and scapha.

of an auricular cartilage flap underneath a bridge of periosteum raised on the mastoid process reported by Demel, and the use of a fascia lata strip passed under a mastoid periosteal bridge and attached to the posterior auricular surface reported by Ruttin.

Eitner attempted to prevent the ugly wrinkling of the skin in the conchal hollow by opening the perichondrium transversely and removing two triangles of cartilage. None of these operations are recommended and are quoted merely to call attention to the objections of the Morestin operation which they attempt to overcome. In spite of this the Morestin operation is still widely used at the present time. In 1941 Cox advocated this operation because it satisfies the patient. As he put it "the patient wants an ear that does not stick out from the head and does not object if the folds and contours of the pinna are not exactly the

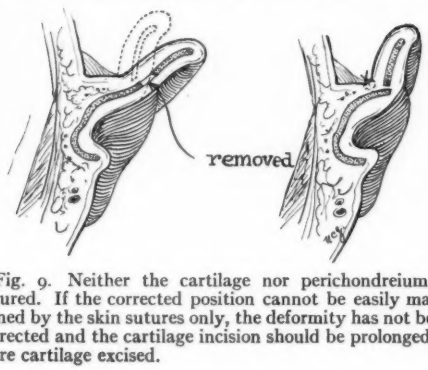


Fig. 9. Neither the cartilage nor perichondreium is sutured. If the corrected position cannot be easily maintained by the skin sutures only, the deformity has not been corrected and the cartilage incision should be prolonged or more cartilage excised.

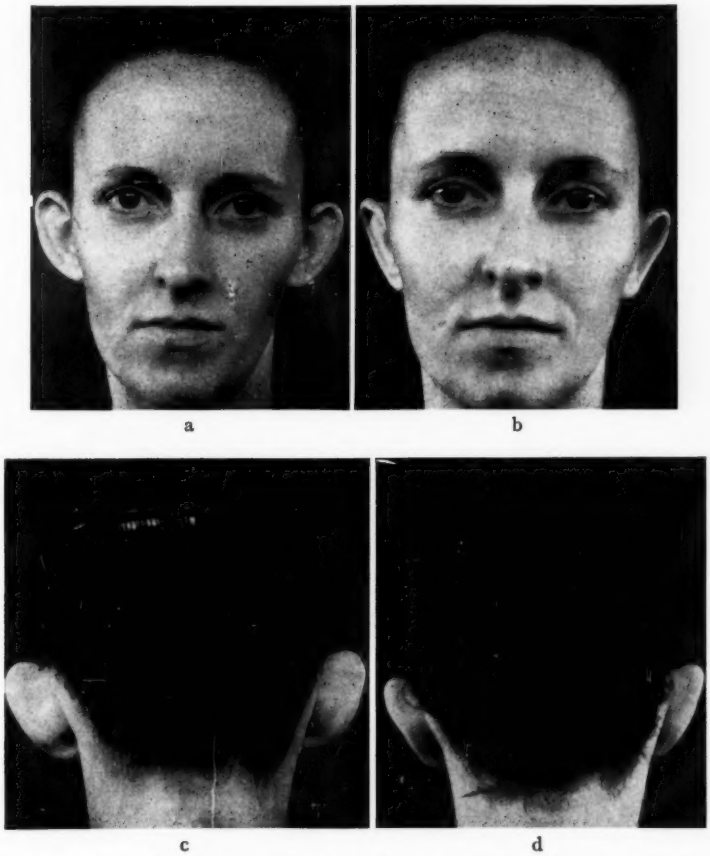


Fig. 10. a, c, Abnormal protrusion of ears in a woman who desired correction because of thinning of the hair. b, d, Postoperative appearance following the Morestin operation. Note that the ears are closer to the head but the wide conchal-scaphal angle is still present.

same as before." In our opinion the only argument for the operation is its simplicity. It should be used only in those instances in which the deformity is slight.

In 1910 Luckett reported an operation which attempted to correct the protrusion and at the same time form an antihelical ridge. He recognized, as he clearly states, that the usual view that the abnormal prominence was due to an increase in the cephaloauricular angle was incorrect. He noted that most protruding ears had a near or complete absence of the antihelix ridge with a shallow or absent triangular fossa. Recognizing the abnormalities in formation of the cartilage he attempted to restore the ear more nearly to normal by an operation designed to form an antihelix ridge. In the Luckett operation an elliptical excision of the skin is made on the posterior surface of the ear in line with the antihelix. An ellipse of cartilage of the same size as the excised skin is removed with care not to perforate the skin of the ear anteriorly. The cut edges of the cartilage are buckled anteriorly, back to back, to form the antihelix ridge and sewed in position with interrupted stitches in the perichondrium posteriorly.

This contribution of Luckett's was a decided advance and most of the operations described since that time have been modifications and gradual improvements of the concept of forming an antihelix ridge.

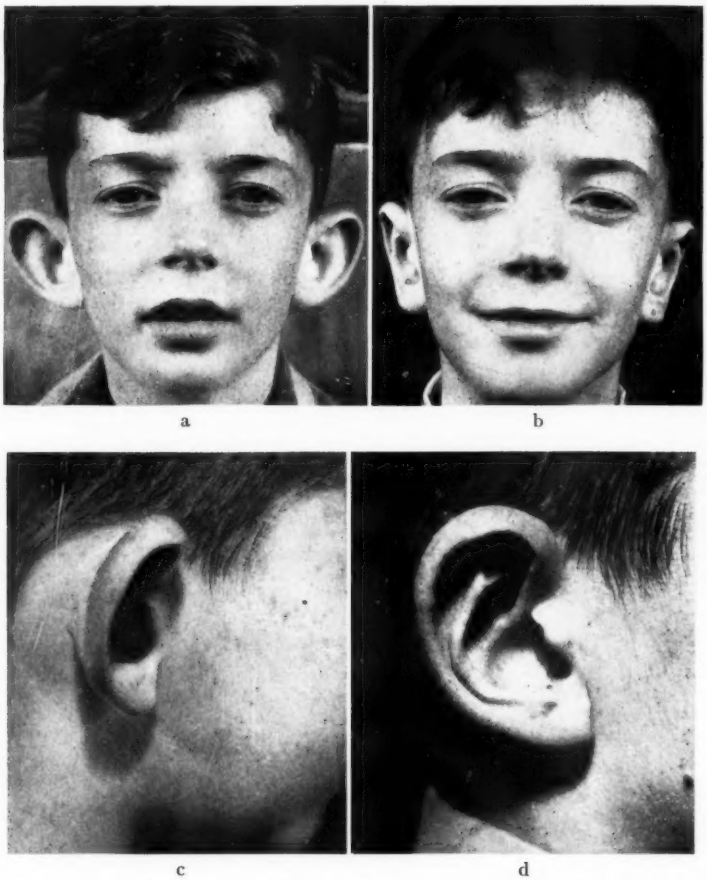


Fig. 11. a, c, Excessive protuberance which the lateral view shows is due to a scaphoconchal angle of about 180 degrees. b, d, The appearance following operation described. The antihelix and the triangular fossa are well formed and the proportions of the ear appear normal. The left ear was corrected a little too much since sight of the helix is partially lost from direct front view.

In 1937 Davis and Kitlowski described the procedure which they had used for a number of years. This combined the Morestin and Luckett procedures in that an ellipse of skin is removed from the postauricular sulcus but after the skin is undermined laterally the ellipse of cartilage is removed along the marked outline of the antihelix. The cartilage is then sewed in buckled fashion to form the antihelix as in the Luckett operation. From the illustrations in this report it would seem that this operation definitely corrects the protuberant appearance but obliterates the postauricular sulcus to such an extent that the posterior view is somewhat abnormal. In addition the lateral views show the antihelix well formed but the scapha is broader and more flat than normal. This flatness is probably due to the postauricular sulcus excision of skin.

Since this report there have been others which are in the main no different other than in minor details.

MacCollum, in 1938, reported an identical procedure which he stated was applicable in all cases of protuberance. In addition he described 2 other procedures. One of these is the Luckett operation with no modification other than that an ellipse

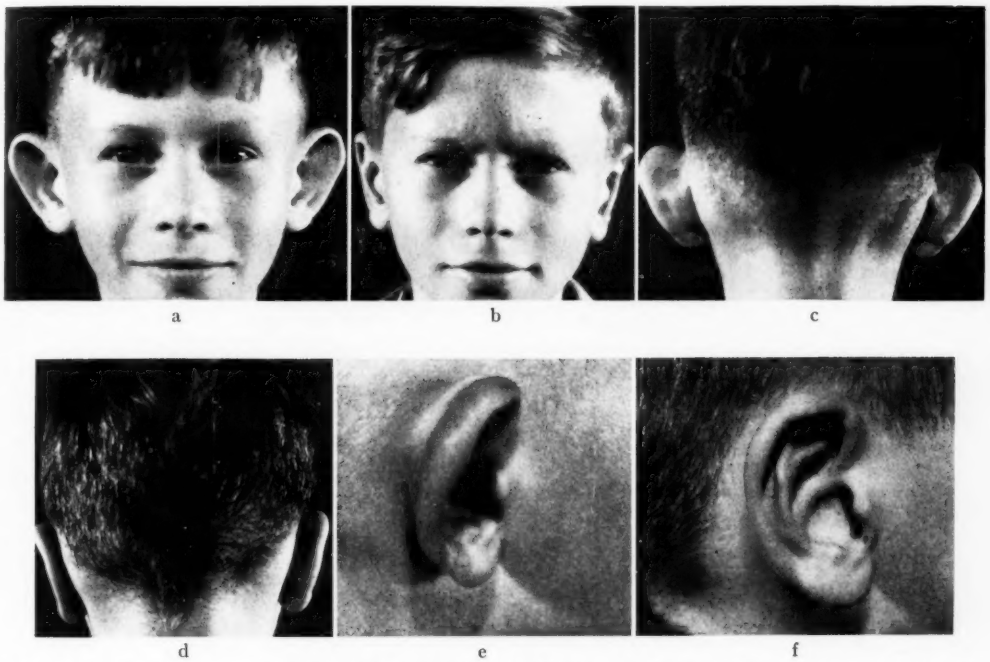


Fig. 12. a, c, e, Preoperative appearance of boy with protruding ears due to increased conchal-scaphal angle. b, d, f, Postoperative photographs. The satisfying thing about the operation which has been described is that, as in this instance, the ears do not look manufactured. The configuration and the position are both normal so that the ear does not appear pinned back when viewed from any position.

of skin is not removed. He states that this operation is applicable when the pinna of the ear is prominent and the conchal cartilage relatively normal. The third method described is essentially the same as the first: a combination of the Morestin-Luckett procedures with minor differences in the amount of skin and the shape of the excised cartilage. The proximal cartilage is also anchored to the galea where the skin is excised.

In 1940 New reported an operation which, as he states, did not differ materially from the procedure reported by Davis and Kitlowski. However, there was one thing in this report which was a definite evolutionary step in the right direction. He said that in certain instances it might be necessary to remove a separate piece of cartilage along the line of the posterior crura of the antihelix. In other respects the operation is the same combination of Morestin and Luckett operations described by Davis and Kitlowski.

The same is true of a report by Baxter, in 1941.

It will be observed that in most of the operations described there is the objective in more or less degree of attempting to hold the ear closer to the head. The only one that clearly attempts to discard this idea is the Luckett operation in which the attempt is solely to reconstruct an antihelix.

The Davis-Kitlowski operation and the various modifications of it still tacitly cling to the idea of approximating the ear to the head, even though an attempt is made to reconstruct the antihelix. The reason given by Luckett and by Davis for the reconstruction of the antihelix is that the spring of the cartilage is broken and the folded edges of the cartilage form a buttressing ridge which supports the ear in the more normal position.

The operation which we have gradually developed is based on a different concept. We believe that the abnormal protuberance is due to an increase in the normal right angle formed by the junction of the scapha and conchal cartilage. This makes the antihelix ridge appear less prominent. At first sight it might appear that this is a mere toying with words but if this reverse concept of the cause of the deformity is so, then surgery should attempt to change the angle and the recon-

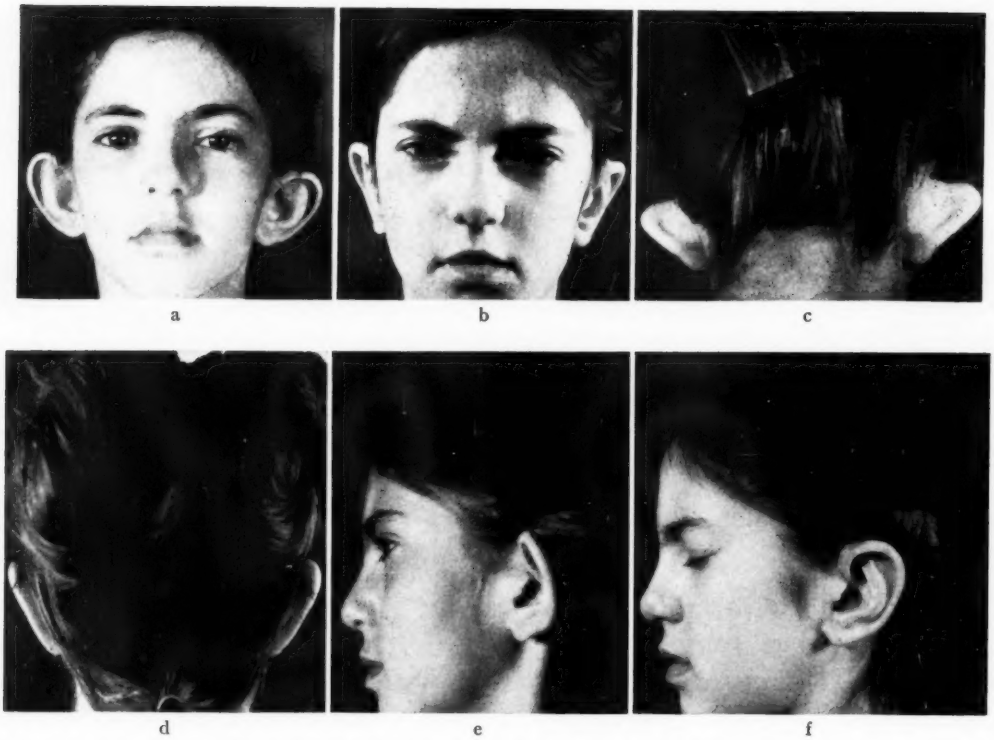


Fig. 13. a, c, e, Extreme protuberance due to a concha-scapha angle of almost 180 degrees calls for correction even in a girl. This school girl could not hide her ears with her hair and was subjected to ridicule by her schoolmates. b, d, f, Appearance after reduction of the scapha-concha angle to approximately 90 degrees.

struction of the ridge which results is secondary. If the wide angle is the sole cause of the deformity, then skin excisions on either side of the postauricular sulcus are unnecessary and even to be avoided since they more or less change the normal posterior view and make the ears appear attached too tightly to the head. If the angular relationship of the concha to the head is not abnormal, then excisions of cartilage at the junction of head and concha or attachment of the conchal cartilage to the mastoid galea are incorrect.

Ideally the objectives of the operation should be to set the scapha on the concha at a normal angle, not disturb the normal postauricular sulcus, and to restore the configurations of the ear to normal. The restoration of configurations should be such that, when viewed from the front, the helix is just visible as a peripheral margin external to a visible antihelix. If the scapha is drawn too far toward the head, the helix is hidden. Laterally the antihelix should be well formed, the triangular fossa a definite depression and the scapha normally proportioned.

OPERATIVE TECHNIQUE

Some prefer to operate under local anesthesia but as the majority of these patients are children, we prefer general anesthesia. Although Davis states that he operates with the patient on the face so that both ears are visible, we find that this position is an awkward one for access to the field. We drape both ears so that, with the patient on the back, the head can be turned from side to side as the operation progresses to compare symmetry. The line of the antihelix is marked out by puncturing the ear anteriorly along the proposed line with a hypodermic needle dipped in methylene blue (Fig. 4). This marking extends up to the beginning of the triangular fossa where it branches to follow the anterior and posterior crura. An incision is then made on the posterior surface of the ear along the crease where the scapha and concha

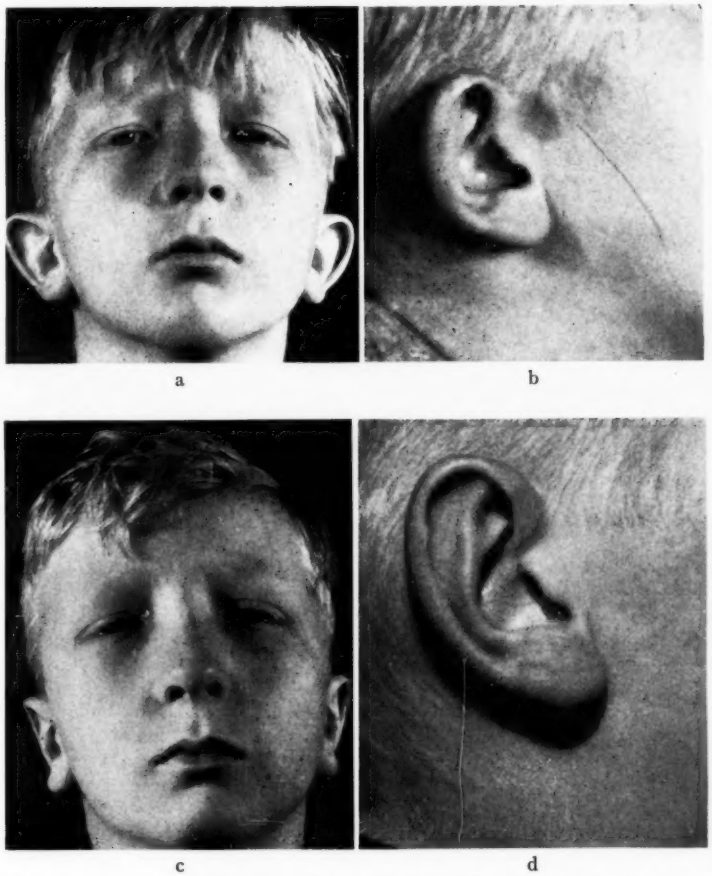


Fig. 14. a, c, Minor protuberance of only the pinna. The triangular fossa is formed and in this instance the cartilage incision followed only the superior crus. An ellipse of cartilage was removed from the scapha superiorly and this alone sufficed to correct the condition as shown in b and d.

join (Fig. 5). The skin is dissected from the cartilage on either side for ¼ to ⅜ of an inch. An incision is made through the cartilage along the line of the marked antihelix; at its superior end the cut follows the line of the anterior crus. A separate incision through the cartilage extends longitudinally through the entire extent of the cartilage dividing the ear into scapha and concha, the only exception being that at the superior end a small bridge of the helix is left (Fig. 6). A long thin ellipse of cartilage is removed, in its superior portion this ellipse is removed to the scaphal side of the cut, but inferiorly from the concha (Fig. 7). By so doing the pinna and the concha are both slightly reduced in size. The scapha can then be slipped over the concha so that it rests on it at a right angle. If the incision does not extend the full length of the cartilage, this cannot be done. The scapha will rest on the concha in correct position without tendency to return to the deformed position if the cartilage excisions have been made correctly. If sutures in the cartilage are necessary to maintain correction, the removal of cartilage is inadequate, or the cut has not extended the full length of the cartilage. The cut along the posterior crus is usually sufficient to break the spring of the cartilage and allow the triangular fossa to form. In extreme deformities it may be necessary

to remove a thin cartilage strip along this line. The repositioning of the scapha on the concha causes a moderate overlapping of the skin along the posterior incision (Fig. 8). This excess skin is removed and the skin edges are sutured. No internal sutures whatever are used. Thus the new line of the antihelix is not formed as in the previously described operations but by the protruding cut edge of the conchal cartilage and the excess of skin anteriorly (Fig. 9). The ears are held in correct position by snug dressings of cotton moistened in saline. This is molded into the posterior sulcus and to fit the external convolutions of the ear. Considerable gauze is packed over this, and the mass of dressings are held firmly in place by a bilateral mastoid type of head dress. This is left in place 10 days, and it should be made certain that it is kept tight at all times. At the first dressing the sutures are removed and a similar dressing is reapplied. At the end of a week this is removed and dressings discontinued.

SUMMARY

Operative attempts to correct abnormal prominence of the ears have fallen into 3 groups: (1) those which attempt to place and hold the ear closer to the head; (2) those which attempt to reconstruct an antihelix ridge; and (3) those which combine the two procedures.

In our opinion abnormal protuberance of the ears is due to the fact that the scaphal portion of the ear is set on the conchal portion at an angle greater than the normal 90 degrees.

This deformity can be corrected and the normal configuration restored by the operation described. In brief, an incision is made on the posterior surface of the ear at the junction of the scapha and concha. An incision is made through the entire length of the cartilage in this same line following the superior crus at the pinnal end. An ellipse of cartilage is removed to the scaphal side of this incision superiorly and from the concha inferiorly. The scapha is set on the concha at right angles where it will remain without holding sutures. The triangular fossa is formed by an incision through the cartilage along the inferior crus. Skin overlap is excised and the skin is sutured. The antihelix is automatically formed by the cut edge of the concha. Retentive dressings hold the ear in accurate position during healing.

This operation corrects the abnormal protuberance, restores the normal configuration, and does not produce the abnormal appearance of the ear, being too close to the head which sometimes results from operations which remove skin from the postauricular sulcus as is shown by Figures 11 through 14.

REFERENCES

1. Baxter, Hamilton. Canad. M. Ass. J., 1941, 45: 217.
2. Cox, G. H. Laryngoscope, 1941, 51: 791.
3. Davis, J. S., and Kitlowski, E. A. Surgery, 1937, 2: 835.
4. Demel, R. Wien. klin. Wschr., 1935, 48: 1185.
5. Eitner, E. Wien. klin. Wschr., 1937, 50: 1206.
6. Fomon. Surgery of Injury and Plastic Repair. Baltimore: Williams and Wilkins, 1939.
7. Luckett, W. H. Surg. Gyn. Obst., 1910, 10: 635.
8. MacCollum, D. W. J. Am. M. Ass., 1938, 110: 1427.
9. Morestin, H. Rev. orthop., Par., 1903, 4: 289.
10. New, G. B., and Erich, J. B. Am. J. Surg., 1940, 48: 385.
11. Ruttin, E. Mschr. Ohrenh., Wien., 1910, 44: 196.

VARIATIONS OF THE MALE SACRUM

Their Significance in Caudal Analgesia

GORDON S. LETTERMAN, M.D., and MILDRED TROTTER, Ph.D., St. Louis, Missouri

THE pelvis, of which the sacrum is a constituent part, presents the most marked sexual differences in the skeletal framework of the human body. Since there are definite indications for caudal analgesia in urology, proctology, and general surgery and since the widespread application of the procedure by obstetricians (1) may be expected to stimulate its further use in these fields, it is appropriate to study the male sacrum, apart from the female, in its relation to the technical procedure of caudal block.

The purpose of this paper is twofold: one, to present the gross anatomy of the mid-dorsal region of the male sacrum with particular reference to the hiatus sacralis; and two, to point out and examine those features and variations of especial importance in caudal block technique. The data and deductions are based upon observations and measurements made on 553 male sacra of which 296 are white and 257 are negro. The bones studied were chosen at random from some 1,100 male skeletons contained in the Terry Anatomical Collection.

OBSERVATIONS

The laminae of the fourth and of the fifth sacral vertebrae fail to meet in the midline and thus an opening is created at the caudal end of the bony spinal canal known as the hiatus canalis sacralis. Dorsally, the hiatus resembles an isosceles triangle with its base at the level of the middle third of the body of the fifth sacral vertebra and its apex at the lower third of the body of the fourth sacral vertebra. This is the textbook picture and the one most often seen. Variations from this pattern, however, are present in a large number of bones.

In this series the width of the base has a mean of 17 millimeters; it varies from 7 millimeters to 26 millimeters. The length of the hiatus from base to apex is 22.5 millimeters; there is a range from 0 millimeter to 60 millimeters. The apex is located most often at the lower third of the body of the fourth sacral vetebra; it occurs at this level in 32 per cent of the bones. In one-half of the sacra the apex is at points superior (cephalad) to the lower third of the body of the fourth sacral vertebra; the highest is found at the upper border of the body of the second sacral vertebra. In the remaining 18 per cent it lies at various levels inferior (caudad) to this region, in the extreme cases extending as far inferiorly as the lower third of the body of the fifth vertebra. A male sacrum with a hiatus of average dimensions is depicted in Figure 1a; it presents the same general outline as the typical female (5), but exceeds it slightly in all dimensions. At the apex of the hiatus the sacral canal has as in the female (5) a mean anteroposterior diameter of 5.3 millimeters with a range from 0 millimeter to 11 millimeters (Fig. 1b). This diameter is 2 millimeters or even less in as many as 4 per cent of the bones.

The dorsal bony wall of the sacral canal exhibits a multiplicity of peculiarities. Complete agenesis of this structure occurs in 10 sacra or nearly 2 per cent (Fig. 2); this variation was encountered only twice in 774 female sacra or in less than 0.3 per cent (5). Laminar deficiencies are frequent; superiorly the posterior canal wall may extend only to the level of the body of the third or of the second sacral vertebra; inferiorly, the result of this type of deficiency is a long hiatus (Fig. 3). Apertures (unilateral, bilateral, and seriational) of the canal wall are encountered at many levels. The distance from the apex of the hiatus to these apertures and to the upper limit of the bony wall of those sacra with superior laminar deficiencies is 70 millimeters or less in 26 per cent; 50 millimeters or less in 11 per cent; and 20 millimeters or less in 5 per cent.

Variations are encountered which so alter the bony prominences of the sacrococcygeal region as to make them valueless as a guide to the location of the hiatus; the lumen of the sacral canal may in such instances be of average or of even greater than average diameter. An overgrowth of bone, obscuring or obliterating the hiatus and prolonging the posterior sacral canal wall inferiorly, occurs to a pronounced degree in 5 bones of the series (Fig. 4). More frequently the sacral cornua are absent or markedly flattened. Occasionally a hiatus is seen which is bilaterally asymmetrical (Fig. 5).

Aided by a grant from the U. S. Public Health Service.

From the Department of Surgery and the Department of Anatomy, Washington University School of Medicine.

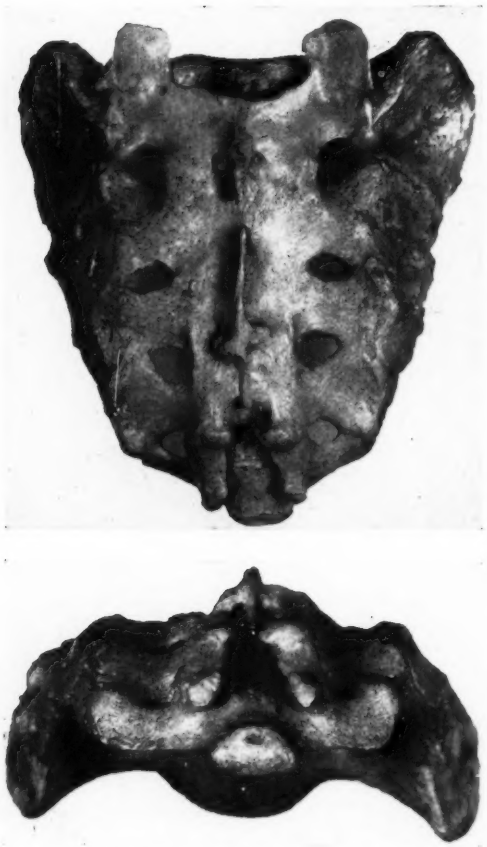


Fig. 1 W. U. 829. a, above, Hiatus canalis sacralis of typical dimensions. b, Sacral canal with a somewhat greater than average anteroposterior diameter at apex of hiatus.[1]

The hiatus or the lumen of the sacral canal may be reduced or blocked at some point by a dorsalward projection from the ventral wall (Fig. 6), by a transverse fold in the posterior wall, or by an excessive flattening of either wall in relation to the curve of the other.

The generally contracted sacrum and the four-vertebrae sacrum are characterized by dorsal walls which although completely developed are of markedly diminished length. In the two sacra of this study which are composed of but four vertebrae the dorsal wall lengths are 38 millimeters and 56 millimeters (Fig. 7).

[1]The photographs for this figure and for succeeding figures were made by Mr. M. B. Rhoades of the Department of Anatomy.

DISCUSSION

The canalis sacralis is that portion of the vertebral canal within the sacrum; it encases the inferior extent of the dura and arachnoid, the lower components of the cauda equina, and the filum terminale; it terminates in the hiatus. The subarachnoid space extends caudally in the canal to the level of the body of the second sacral vertebra (3, 4). Those anatomical features and variations which essentially diminish the distance between the point of entrance of the caudal needle into the canal and the inferior limit of the subarachnoid space are deserving of first consideration in the problem of caudal anesthesia. Labat wrote: "The presence of an unusually large hiatus as the result of the non-closure of the lower half or two-thirds of the posterior wall of the sacral canal, should not be overlooked. In such cases caudal injection should be made with great caution and occasionally avoided, because it may prove dangerous to life, owing to the risk of puncturing the dural sac and making an intradural injection" (Fig. 3). Four additional varieties of sacra whose structure is predisposing to subarachnoid injection are encountered with sufficient frequency to constitute a real hazard if unrecognized. First, the posterior wall of the sacral canal may be open in its entirety (Fig. 2); in such situations the caudal needle can be inserted easily into the sacral canal throughout its length. The complete agenesis of the dorsal wall may indeed represent

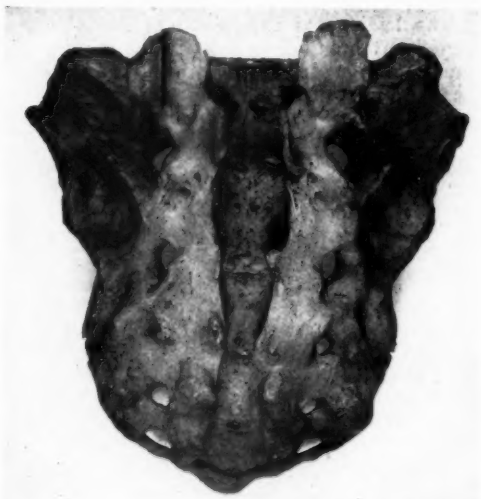


Fig. 2 W. U. 529. Complete agenesis of dorsal bony wall of sacral canal.

one of the rare contraindications to caudal anesthesia because of this very real possibility of piercing the dura. Second, large midline apertures may, through erroneous interpretation of palpation lead to and permit the insertion of a needle at a point superior to the apex of the hiatus and thus in close proximity to the subarachnoid space. Third, the sacrum may be composed of but four vertebrae (Fig. 7). This anomaly is particularly important if such a reduction of components is not a result of the lumbarization of the first sacral vertebra but rather of a caudal shift in the sacrococcygeal segments. Fourth, the generally contracted sacrum which at first glance may appear to be perfectly normal, presents a proportionate shortening of dimensions. The needle used customarily in caudal block is 8 centimeters in length. In the four vertebrae sacra of this series the average distance from the apex of the hiatus to the lower border of the second sacral vertebra is 1.7 centimeters; generally contracted sacra are found in which the measurement is 3 centimeters.

Subcutaneous deposition of the anesthetic agent may occur as the result of dorsal wall agenesis, apertures, and deficient or low-lying superior laminae. Obliteration of the hiatus or canal is due to dorsalward projecting vertebral bodies,

Fig. 3 W. U. 1324. Superior laminar deficiency; a long hiatus in which the apex reaches the level of the lower one-third of the second sacral vertebra.

Fig. 4 W. U. 515. a, above, Bony overgrowth extending the dorsal wall of the canal caudally. b, Anteroposterior diameter of the sacral canal unaffected by the bony overgrowth.

dorsal wall folds, excessive flattening of either canal wall, and bony growth within the hiatus. This last obstructive element which is more pronounced in the male, protrudes as a circumscribed sessile nodule of bone from the posterior surface of the vertebral body (Fig. 6). Either a very small anteroposterior diameter of the canal at the apex of the hiatus or complete occlusion at this point make caudal block impossible.

Bony overgrowth (Fig. 4), absence of the sacral cornua, and excessively flat cornua mask the normal landmarks of the hiatus. Labat has called attention to the latter variation; he wrote that, "Palpation of the sacrococcygeal region

Fig. 5 W. U. 986. Asymmetrical hiatus.

occasionally fails to give accurate information, because the cornua are comparatively flat or the thickness of the soft structures overlying them abnormally great."

The hiatus canalis sacralis is variable in extent and form. The recognition of the outline of the hiatus is a desirable refinement of palpation. Both the recognition and appreciation of asymmetrical types (Fig. 5) are essential if the proper correction factor is to be introduced to insure the insertion of the caudal needle into the midline of the sacral canal. This position is believed to be necessary for the even deposition of the anesthetic agent and consequently for a uniformly distributed area of analgesia (2).

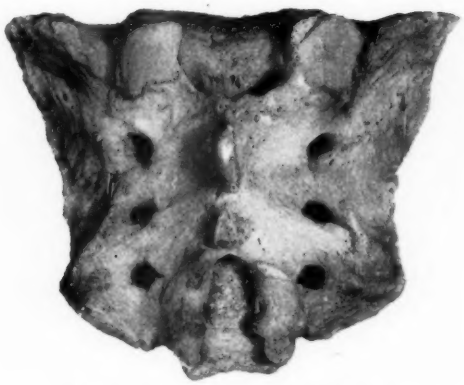


Fig. 7 W. U. 971. Four-vertebrae sacrum.

A thorough knowledge of the anatomical features of the dorsum of sacrum which have been described in this article will inevitably lead to the reduction in the number of failures of the skilled clinician in his administration of caudal analgesia.

Fig. 6 W. U. 784. a, at left, Hiatus with circumscribed nodule of bone extending from dorsal surface of body of vertebra. b, above, Projecting nodule within the hiatus.

SUMMARY

Variations in the anatomy of the mid-dorsal region of the sacrum and their significance in the administration of caudal analgesia were studied in a series of 553 male bones.

1. In 50 per cent the hiatus canalis sacralis reached a level on the sacrum cephalad to the level of the lower third of the body of the fourth sacral vertebra.

2. In 26 per cent deficiencies existed in the dorsal wall of the sacral canal which might permit exit of the needle.

3. In 4 per cent the anteroposterior diameter of the sacral canal at the level of the apex of its hiatus was 2 millimeters or less.

4. Other variations include obliteration of the lumen of the sacral canal, masking of the palpable landmarks in the region of its hiatus, and a shortened sacrum either as a result of a reduction in the number of elements or from general contraction.

REFERENCES

1. HINGSON, ROBERT A., and EDWARDS, WALDO B. J. Am. M. Ass., 1943, 123: 538–546.
2. LABAT, GASTON. Brit. J. Anaesth., 1925, 3: 5–20.
3. LARSELL, OLOF. The Nervous System, Section VIII in Morris' Human Anatomy, 10th ed. Philadelphia: The Blakiston Co., 1942.
4. RANSON, STEPHEN WALTER. The Anatomy of the Nervous System. 7th ed. Philadelphia: W. B. Saunders Co., 1943.
5. TROTTER, MILDRED, and LETTERMAN, GORDON S. Surg. Gyn. Obst., 1944, 78: 419–424.

EDITORIALS

SURGERY
Gynecology and Obstetrics

FRANKLIN H. MARTIN
Founder and Managing Editor
1905–1935

LOYAL DAVIS, EDITOR

Associates
SUMNER L. KOCH MICHAEL L. MASON

DONALD C. BALFOUR, *Associate, Editorial Staff*

MAY, 1944

ACUTE OBSTRUCTION OF THE COLON

IT is conservatively estimated that 20 per cent or more of the patients with acute obstruction of the colon lose their lives. A better comprehension of the etiology, the diagnostic criteria, the pathology, and the proper methods of treatment should improve this mortality.

The etiology of large bowel obstruction is quite varied; however, a fact worthy of emphasis is that carcinoma produces obstruction in this part of the intestinal tract in 80 per cent or more of the cases. Statistical data indicate that about 10 per cent of all malignant lesions of the colon produce obstruction and, of these obstructions, 7 out of 8 are in the left half. Obstructions of the colon due to malignant disease occur mainly in elderly persons, for 70 per cent of the patients with cancer of the colon are over fifty years of age. Therefore, when an elderly patient is sick with an obstruction of the large intestine, the most probable lesion is an occluding carcinoma of the left colon. The next most frequent causes of obstruction here are volvulus, diverticulitis, chronic inflammation, benign strictures, and intussusception.

The clinical features of obstruction develop more slowly in occlusions of the large intestine than in those which occur in the small bowel. However, when the obstruction has persisted long enough that the blood supply of the intestine is becoming impaired, the patient will frequently pass rapidly into a serious state and in a question of hours his condition may become hopeless. The marked biochemical changes which develop rapidly in obstruction of the small intestine are not seen in occlusions of the colon. The diagnosis of obstruction, its etiology, and its location can usually be made by an analysis of the history and physical findings supplemented by a scout film of the abdomen.

The proper treatment of obstruction of the large intestine will be modified somewhat by the nature of the pathology producing the occlusion. Obstructions due to bands usually demand only the severance of the bands. When due to benign stricture, some type of enteroanastomosis around the obstructing segment will usually be an adequate method of treatment. Torsion of the intestine is treated by a reduction or resection of the volvulus, this depending on the viability of the obstructed loop. Chronic or subacute obstructions, occasionally produced by endometrial adenomas, can be controlled usually by surgical attention to the female generative organs or by means of irradiation therapy. Diverticulitis seldom produces complete obstruction and an occlusion due to it can usually be decompressed by medical management. Only in rare in-

stances does a surgical decompression become necessary.

Since 80 per cent or more of the obstructions of the large intestine are due to a malignancy, the predominating question to answer is what is the preferable management for a patient with an occlusion of the colon due to a carcinoma. To cure this patient, it is necessary to resect such a lesion widely. Experience has proved that a primary resection of the colon should never be done in the presence of an acute obstruction which is due to a neoplasm, for it is unnecessary and the mortality is prohibitive. It is vital to recognize that this patient has two conditions—a carcinoma and an acute obstruction—and then evaluate the relative primary importance of each. The carcinoma is a slow-growing, chronic lesion which has existed for months, while the obstruction is an acute process of only hours' duration and will soon prove fatal unless relieved because the circulation of the intestinal wall is endangered by it.

Certainly the immediate institution of measures to protect the viability of the intestine is of primary importance. Research studies appear to confirm that, as long as the bowel is viable, transperitoneal absorption of toxic products and permeation of the intestinal wall by virulent bacteria do not occur. The chief factor threatening the viability of the intestine in the majority of obstructions of the large bowel, when strangulation obstructions are excluded, is the increased intraluminal pressure from colonic distention. Temporizing measures and prolonged attempts to relieve this condition by medical treatment frequently will force such a patient to accept a hazardous rather than a relatively safe surgical decompression. Certainly then, the imperative need of the patient is an operative procedure which will relieve this distention. A cecostomy or colostomy in the transverse colon is indicated, and, when such an operation is done promptly with little manipulation and without exploration, it will usually prove to be life-saving.

When proper evaluation is made of what a surgical decompression does for such a patient, the rationale of the procedure becomes apparent, for it will relieve the distention and then normal blood supply to the bowel will be restored. The infection within the intestinal wall will subside. Also the number and virulence of the bacteria in the lumen will diminish greatly. The ulcers on the mucosal surface will heal and the edema of the intestinal wall will disappear frequently restoring a patent lumen at the point of the constriction. When this occurs, it will permit cleansing of the colon by a through-and-through irrigation. The general effects obtained are that the biochemical changes will become normal and the nutritional status of the patient will again be restored.

The obstructed colon usually is decompressed adequately for a safe resection later. A functioning cecostomy or colostomy prevents colonic distention following the resection when it is performed, and thereby avoids tension on the suture line and impairment of the blood supply to the anastomosis. It aids healing of the resected colon by keeping it at rest. The patient with a functioning cecostomy can safely take food soon after the resection. The mortality for the resection of the obstructed left colon will be diminished greatly when a preliminary decompression has been performed.

The reason for the high mortality which accompanies primary resections of the obstructed colon will be more readily understood when the local and general status of the patient is given consideration. Such a patient is in a poor physical state to undergo a major surgical operation because there is marked intes-

tinal distention; the blood supply to the intestinal wall is impaired; the tissues are edematous and friable; there are ulcers of the mucosa; infection is present within the intestinal wall; and the lumen of the bowel is teeming with highly infectious bacteria predisposing to peritonitis. The proper healing of the anastomosis following a resection will be doubtful. Furthermore, this patient is dehydrated, somewhat starved, and is becoming exhausted, and there even may be signs of impairment of the general circulation with impending shock. When due concern is given to these facts, the hazard of a primary resection of an obstructed colon will be comprehended more fully, and the wisdom and urgent need of a first-stage surgical decompression will be appreciated. G. V. BRINDLEY.

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

IN the preface to *Synopsis of Diseases of the Skin*[1] the authors state, "This book is intended to present in compact form a general view of diseases of the skin." In this purpose they have succeeded admirably for the volume is simple, practical, condensed, and yet packed with information. After discussing briefly but adequately the anatomy, embryology, physiology, etiology, symptomatology, diagnosis, and treatment in short chapters, they have grouped the various diseases on an etiologic basis. This plan should help the student as well as provide the teacher with a systematic outline to follow.

All of the common skin diseases and many of the rarer ones are discussed briefly, but none of the salient features are omitted. As in all Sutton books, there are many excellent illustrations. In this small volume there are 413, all of them excellent. There are many references to pertinent literature scattered throughout the volume, an unusual feature in a book of this type.

The subject of syphilis is well handled, well illustrated, and the treatment is clear, concise, and up to date. One might call attention to several omissions in the treatment outlined for some of the diseases. For example, no mention is made of Fowler's solution or sulfapyridine in the treatment of dermatitis herpetiformis, the use of bismarsen in chronic discoid lupus erythematosus, and the intravenous administration of sodium iodide in herpes zoster. These are, however, minor criticisms in a volume that is otherwise so uniformly excellent. How it is possible to say much in a few words is well shown here. The book is recommended as an excellent textbook for medical students and nurses and could be used with profit by the busy general practitioner.

EDWARD A. OLIVER.

THE appearance of a second edition of Fulton's *Physiology of the Nervous System*[2] makes available once more and in revised form, a remarkably successful book. The first edition published in 1938 and reprinted in 1939 had been out of print for a year.

Except for outdated *Handbuecher* this is the only comprehensive presentation of the subject matter of neurophysiology, a field in which investigation will probably continue to be intensified as a result of the present conflict. This edition devotes considerable attention to neurological developments initiated since 1938, and the author states in his preface, "The central nervous system looms large in war time when injuries of the whole cerebrospinal axis, as well as of peripheral nerves, occur in large numbers; such injuries take origin not only from mechanical, chemical, and nutritional insults but they also arise from exposure to low oxygen tensions, high accelerations and other stresses created by the fast-moving engines of modern warfare. In a textbook for students, the fundamentals cannot be neglected, but in these critical times it has seemed essential to emphasize practical applications from the outset."

These recent developments have been woven into an orderly, progressing account of the subject. Commencing with sensory and motor units and discussing the most recent knowledge of the relation of acetylcholine formation to neural activity, the author passes to the reflex activity of the spinal cord, and thence to suprasegmental mechanisms of the medulla oblongata and midbrain by the action of which these reflexes are integrated. The autonomic system and hypothalamus are then considered in consecutive chapters, and the section on the brain stem is concluded with a discussion of the thalamus. From this subject the account logically passes to the sensory areas of the cerebral cortex, and consideration is given to the newer information brought by electrophysiological studies of the sensory representation in the brain.

The motor representation in the cerebral cortex is then considered in several chapters, following which the basal ganglia and cerebellum are discussed from the point of view, gained from recent studies, of feed-backs to cortical motor mechanisms. In addition to a chapter on the frontal association areas, the volume is concluded in a venturesome manner for a physiologist with a section on the psychological aspects of cerebral activity.

As in the first edition, each chapter is preceded by a charming historical note in which with a few broad strokes the main early developments in that field are outlined. Adequate illustration and extensive reference to the literature are found throughout the text, and in controversial discussion advance of one point of view is associated with accompanying reference to others. All references are gathered together at the conclusion of the text, and preceding the index, into a bibliography of some 65 pages.

The great literary gift of the author and his broad integrative command of the field of neurophysiology, abetted on occasion by the collaboration of former

[1] SYNOPSIS OF DISEASES OF THE SKIN. Richard L. Sutton, M.D., and Richard L. Sutton, Jr., M.D. St. Louis: The C. V. Mosby Co. 1942.

[2] PHYSIOLOGY OF THE NERVOUS SYSTEM. By John Farquhar Fulton, M.A., D.Phil., D.Sc. (Oxon.), S.B., M.D. (Harv.). 2d ed. London, New York, and Toronto: Oxford University Press, 1943.

students and associates, make this volume a potential source of keen enjoyment and of invaluable reference to everyone interested in neurology.

H. W. MAGOUN.

THE new 760 page volume entitled *The Hospital in Modern Society*[1] is the means of bringing the thinking of the leaders of the hospital field together in book form. The material has been obtained from periodicals of special interest to hospital administrators, from the *Transactions of the American Hospital Association*, as well as from proceedings of various institutes. The subject matter has been extremely carefully selected, well organized, and correlated into pertinent chapter and topic headings.

It is gratifying to note that the editors have been well aware of the need for attention to the philosophical and social side of the concepts of hospital administration. When one sees such names as Goldwater, MacEachern, Munger, Buerki, Faxon, and many others, the reader is assured of the quality of the volume as well as the diversity of opinion.

This book will assume a high place in the published works of interest to hospital people and will be an especially valuable reference book. It should be in a readily accessible place in every administrator's library.

ROGER W. DEBUSK.

[1] THE HOSPITAL IN MODERN SOCIETY. Edited by Arthur C. Bachmeyer, M.D., and Gerhard Hartman, Ph.D. New York: The Commonwealth Fund, 1943.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

A TEXT-BOOK OF PATHOLOGY. Edited by E. T. Bell, M.D. 5th ed. Philadelphia: Lea & Febiger, 1944.

TÉCNICA CIRÚRGICA. By Professor Alfredo Monteiro. Volume III—ABDOME. Books 1 and 2. Rio de Janeiro: Editora Scientifica, 1943.

PRODUCCIÓN CIENTÍFICA Y CULTURAL DE JOSUÉ A. BERUTI. HOMENAJE DE SUS COLABORADORES Y DISCIPULOS DE LA CÁTEDRA DE CLÍNICA OBSTÉTRICA Y DE SUS AMIGOS. Volumes 1, 2, 3, and 4. Buenos Aires: Clínica Obstétrica y Ginecológica "Eliseo Canton," 1943.

VASCULAR RESPONSES IN THE EXTREMITIES OF MAN IN HEALTH AND DISEASE. By David I. Abramson, M.D., F.A.C.P. Chicago, Ill.: The University of Chicago Press, 1944.

ANAIS DO PRIMEIRO CONGRESSO BRASILEIRO DE GINECOLOGIA E OBSTETRÍCIA; ORGANIZADO PELA SOCIEDADE BRASILEIRA DE GINECOLOGIA. Professor Arnaldo de Moraes, President. Vols. 1, 2, and 3. Rio de Janeiro: Rodrigues & C., 1942.

CHIRURGIE DE GUERRE. By le Médecin-Colonel Henri Fruchaud. Beyrouth: Les Lettres Françaises, 1943.

THE PRINCIPLES AND PRACTICE OF MEDICINE; ORIGINALLY WRITTEN BY SIR WILLIAM OSLER, BART., M.D., F.R.C.P., F.R.S., DESIGNED FOR THE USE OF PRACTITIONERS AND STUDENTS OF MEDICINE. By Henry A. Christian, A.M., M.D., LL.D., (Hon.) Sc.D., Hon. F.R.C.P. (Can.), F.A.C.P. 15th ed. New York and London: D. Appleton-Century Co., Inc., 1944.

LITÍASE DO APÊNDICE. By Eurico Branco Ribeiro. São Paulo, Brasil: Sociedade Editora Médica Limitada, 1943.

FEMALE ENDOCRINOLOGY INCLUDING SECTIONS ON THE MALE. By Jacob Hoffman, A.B., M.D. Philadelphia and London: W. B. Saunders Company, 1944.